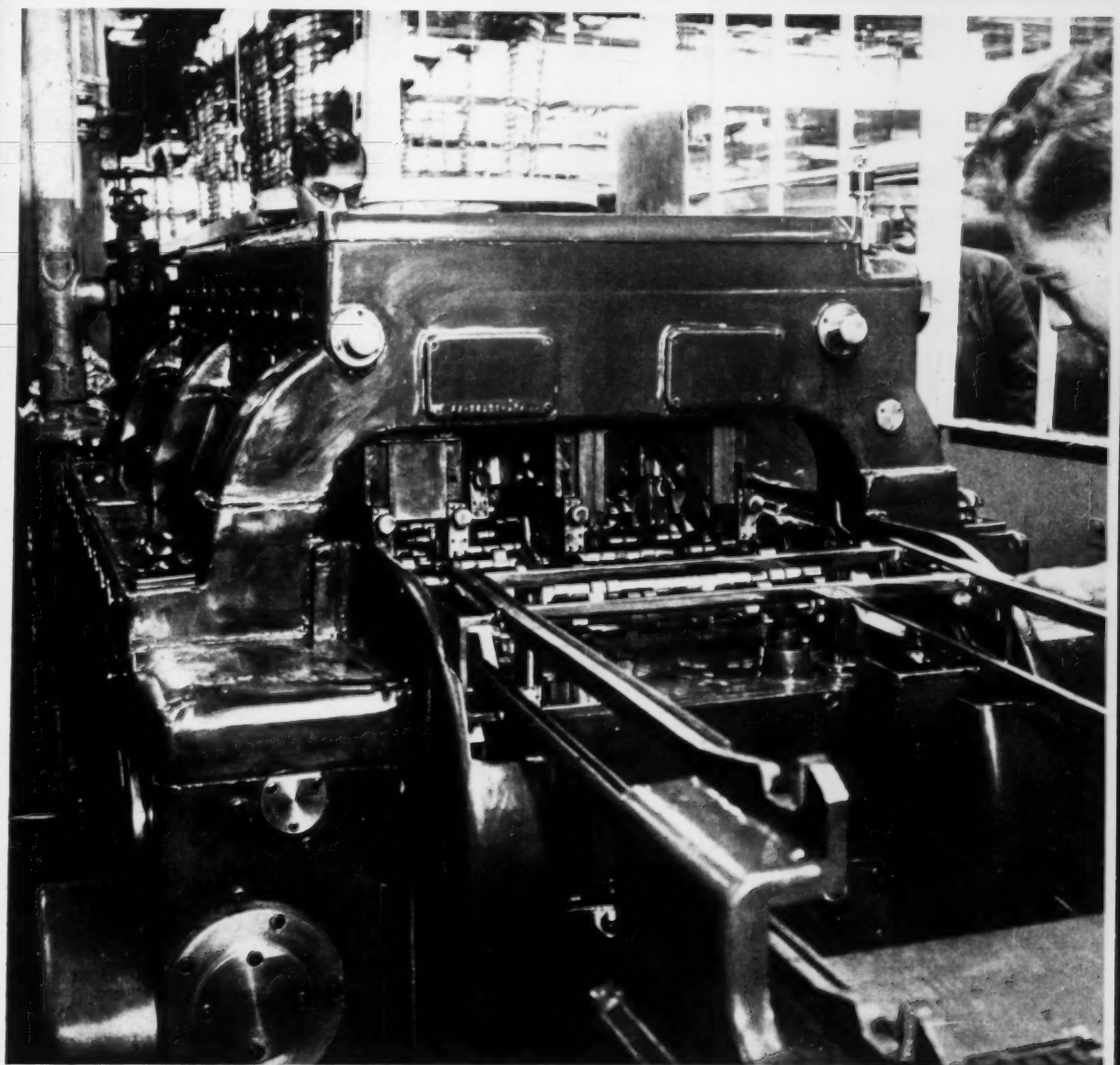
THE MAGAZINE OF

MEASUREMENT and CONTROL

INSTRUMENTS



VOLUME 9

JULY 1936

NUMBER 7

AUTOMATIC INSPECTION OF CAM SHAFTS AT FORD MOTOR CO.
See Page 189

INSPECTING PARTS at FORD PLANT

See Page 189

NOW READY! . . . The Facts About Pressure Compensation *in* Flow Meters

Remember . . .

A flow of steam, at 100 lbs. pressure, will vary 1% each time the pressure varies only 2 lbs.! A flow of air or gas at the same pressure, will vary 2½% each time the pressure varies only 5 lbs.! Foxboro Pressure-Compensating Flow Meters will protect you against metering errors caused by pressure variations. *Get the facts.*

FREE COPY ON REQUEST

Write today—no obligation—for your copy of DMF 692.

THE FOXBORO COMPANY
46 Neponset Ave., Foxboro, Mass., U.S.A.
Branch Offices in 20 Principal Cities

Meters for STEAM GAS WATER AIR LIQUIDS

FOXBORO REG. U.S. PAT. OFF.
FLOW METERS

• COMPLETE INDUSTRIAL INSTRUMENTATION •

Specify genuine Foxboro Humitex Charts—made from paper produced with VERIGRAPH Moisture control. *They hold their dimen...*

Greater Accuracy and Quicker Response

for Separable Well Tube Systems

New Taylor Thermospeed construction makes these systems more efficient than ever before by (1) *speeding up response to temperature changes at the bulb; and* (2) *reducing bulb conduction error to new low point*

WHEN Taylor Engineers developed the new Taylor Thermospeed for separable well systems, they did a complete job.

They recognized the evil of sluggish response to temperature changes at the bulb. So they produced a system that is six times faster than the average separable well system now in service.

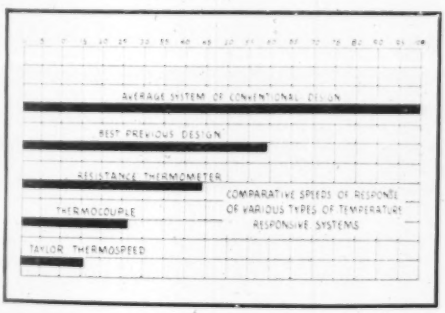
But they did not stop there. They went after another evil—bulb conduction error. And developed a construction that reduces this common error to a negligible quantity hardly worth thinking about any more.

Instead of allowing the temperature of the bulb mounting or of the supporting wall to influence the bulb temperature, the Taylor Thermospeed construction decreases the conduction of heat between bulb and mounting wall so that there is no error in transmitting bulb temperature to the Taylor Recorder or Controller. The bulb in the Thermospeed system responds only to the temperature of the fluid being measured.

ACCURACY and *SPEED*—these are the two vital things you can expect to a greater degree than ever before if you use Taylor's Thermospeed Separable Well tube systems.

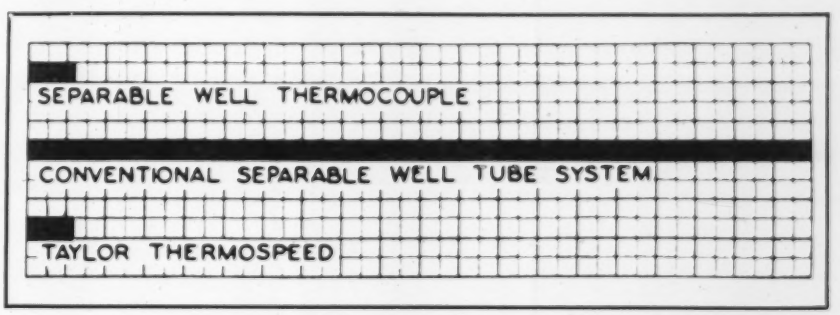
Thermospeed sends bulb temperature changes racing to recording or control instruments. It assures even greater accuracy for Taylor Recording Thermometers and closer regulation for Taylor Controllers.

It will pay you to learn about the new Taylor Thermospeed construction for use on any separable well tube system. You will quickly notice results in better temperature control and more efficient and economical production of finished goods. Ask a Taylor representative about it. Or write direct to Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada. Manufacturers in Great Britain—Short & Mason, Ltd., London, England.


AVERAGE SYSTEM OF CONVENTIONAL DESIGN
BEST PREVIOUS DESIGN
RESISTANCE THERMOMETER
THERMOCOUPLE
TAYLOR THERMOSPEED
COMPARATIVE SPEEDS OF RESPONSE OF VARIOUS TYPES OF TEMPERATURE RESPONSIVE SYSTEMS

QUICKER RESPONSE—THIS CHART shows comparative speeds of response of various types of temperature responsive systems plotted to an arbitrary scale. The comparisons were made with bulbs in standard wells and in a thoroughly agitated water bath.

With the time of response for a conventional tube system as 100, the Taylor Thermospeed responds to the same temperature change in only ⅙ of the time. Note the superior speed of response of the Thermospeed System as compared to a thermocouple and a resistance thermometer of good design.



GREATER ACCURACY—This chart (above) shows clearly how Taylor Thermospeed cuts Bulb Conduction Error far below that allowed by conventional types of Separable Well tube systems.

Taylor

Indicating · Recording · Controlling

TEMPERATURE, PRESSURE AND FLOW INSTRUMENTS

INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

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Courtesy Ford Motor Co.

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Published Monthly on the 15th by
The Instruments Publishing Company
1117 Wolfendale Street Pittsburgh, Pa.

JOSEPH J. VIGNEAU, President†
RICHARD RIMBACH, Vice-Pres.-Treas.

Branch offices
Boston: James Condon, 6 Marlboro St.
New York: Edwin F. Ripley, 118 E. 28th St.
Chicago: R. Farnham, 201 Wells St.
Glendale, Calif.: W. McIntyre, 1115 Tyler St.

Annual Subscription: U. S. $2.00. All other countries $3.00 *payable in advance* (remit by New York draft). Copyright 1936 by The Instruments Publishing Company. Entered as second-class matter January 26, 1932, at the post office at Pittsburgh, Pa., under the Act of March 3, 1879.

†See page 173.

INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

JOSEPH J. VIGNEAU

Joseph J. Vigneau

born in

Detroit

July 27, 1877

died in

Pittsburgh

July 1, 1936

IN a Pittsburgh hospital where for harrowing months of sleepless nights and agonizing days he had valiantly fought the inroads of disease, death came to Joseph J. Vigneau, President of the Instruments Publishing Company. Because of his self-effacing nature, he was but a name to the great majority of our readers; and it is beyond the power of our pen to convey to them an adequate appraisal of Joe Vigneau's combination of charm and strength, of his numerous qualities as a business man, as a civic man, as a family man, as a Man.

Born in Detroit, of French-Canadian stock, Vigneau was educated in that city, graduating from the Preparatory School of the University of Detroit. Gifted with a flair for publicity, he became a theatrical press agent. When President McKinley was shot in 1901, the company Vigneau served was playing Canton, Ohio—McKinley's home town. The mayor declared a two weeks' mourning, and the dramatic troupe disbanded. With a few dollars in his pocket, young Joe went to the railroad station and bought a ticket to "the farthest place where this money will take me." Thus he came to Pittsburgh—unknown, penniless, but with banner flying high. Within two decades all Pittsburgh was taking pride in "our leading industrial publisher" and begging him to serve on the boards of numerous organizations.

Soon after Vigneau came to Pittsburgh—at the age of twenty-five—he founded the Keystone Consolidated Publishing Company and issued annual catalogs and directories serving the mining, quarrying and metallurgical industries. His "one-man company" became a famous institution. In 1925 it was purchased by the McGraw-Hill Publishing Company, and for two years Vigneau devoted himself to traveling the civilized world, but in 1927, back in Pittsburgh, he felt the urge to re-enter the field of industrial publishing and, hearing that Richard Rimbach was organizing the Instruments Publishing Company, he acquired an interest in it. In 1929 he extended his holdings in the firm and became its President and Business Manager. He kept it steady as a rock during the depression . . . Here emotions fill our eyes with tears, rob us of words, and paralyze our hand . . .

INSTRUMENTS' READERS AT WORK

No. 11

EVERETT LeROY GAYHART

Commander, (CC), U. S. Navy

No. 12

HORATIO CLAY SEXTON

Lieut.-Commander, (CC), U. S. Navy

U. S. NAVY YARD
WASHINGTON, D. C.

By M. F. BEHAR

IN visiting a plant where *Instruments'* subscribers work, our purpose usually is to get an article about the results of their work. The results of the work of *Instruments'* subscribers at the Washington Navy Yard must be kept secret, and in visiting this great establishment our purpose was "to give, not to get." However, while admiring various engineering marvels on blueprints and in the making, we came to feel that *you* would enjoy "meeting" (on this page) your fellow-subscribers whose inventive skill and patriotic zeal produce these engineering marvels for your protection.

Space does not permit "introducing" all of these devoted naval officers and civilian experts, but here are two whose work with instruments at the U. S. Experimental Model Basin (see brief list) will interest their colleagues in industry.

A Kentuckian by birth, Commander Gayhart studied at Case ('07-'09) and at the Naval Academy ('09-'13). Followed two years of sea duty, two years of post-graduate work at M.I.T., and two years as war-time inspector of aircraft matériel. Since 1916 he has served in the Naval Construction Corps and now directs several important research and development projects. At his home he rides such scientific hobbies as chemical analysis of minerals, schlieren photography and photomicrography.

Lt.-Com. Sexton, a native of Indiana, was in the Academy's "speed-up" Class of '20, going to sea with the Battle Fleet each summer during the war. A year of post-graduate work at Annapolis and two more at M.I.T. determined that his career would be in the Construction Corps. Since 1923, when not at sea, he has served at various navy yards and taught engineering at the Academy. A year ago he joined Commander Gayhart and has already done work of importance to future naval progress.

(P. S. This two-man team functions under one of *Instruments'* most eminent subscribers, Captain Ernest F. Eggert, the Construction Officer of the Navy Yard and Officer in Charge of the Experimental Model Basin, who in addition to his professional attainments has won fame also as a mathematician, as a designer-builder of astronomical instruments and as an authority on propeller design.)

SOME OF THE INSTRUMENTS USED BY COMMANDER GAYHART AND LIEUT.-COMMANDER SEXTON

STRUCTURAL TESTING LAB.

Baldwin-Southwark 600,000-lb. testing machine with automatic stress-strain recorder-controller;
Baldwin-Southwark 20,000-lb. testing machine with indicator-controller desk;
Strain gage calibrator;
Huggenberger and Tuckerman extensometers; Kenyon break extensometer;
Recording extensometer using standard microscope slides.

PROPELLER-TEST WATER TUNNEL

Pressure control and indicating gages;
Differential manometers & cathetometer;
ERPI high-speed camera;
Model Basin type high-speed camera;
Edgerton Type 548-A stroboscope;
DuMont No. 148 C-R oscillograph;
Westinghouse Osiso oscillograph & Type PA universal oscillograph;
Piezoelectric & other CRO pick-ups;
CRO amplifiers, etc.;
Motor-generator with unique automatic voltage-regulation equipment.

MODEL BASIN & SHIP TRIALS

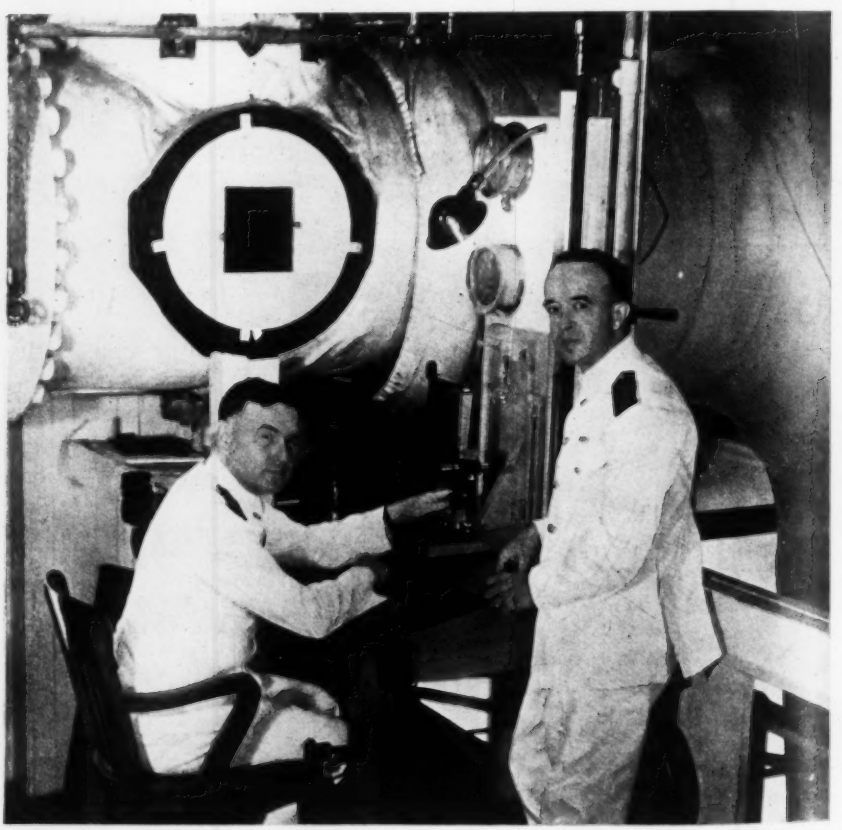
Photographic theodolites for ship turning-circle data;
Two-component vibration-recording apparatus, vibration-recording camera, multiple chronograph, etc., for full-size ship tests;
2 Losenhausen vibration generators;
Ford inductance-balance torsiometer;
Stroboscopic torsiometer.

EXPERIMENTAL DIVING LAB.

Apparatus for simulating depths up to 300 ft.;
Hydrogen detector;
Air flow recorder;
Recompression chamber & accessories;
Biological & biochemical lab. equipment;
Van Slyke blood gas apparatus.

MISCELLANEOUS

Equipments for microscopy, photography (incl. infra-red & color), half-tone engraving for offset process, etc.



Commander Gayhart (standing) and Lt.-Com. Sexton (at pressure and flow-rate instrument station) in front of an observation window of the unique variable-pressure water tunnel where propeller models are subjected to conditions simulating actual service and photographed with high-speed cameras (located behind this section of the tunnel), while oscillographs measure effects which escape photographic detection.

THE MONTH'S NEW INSTRUMENTS

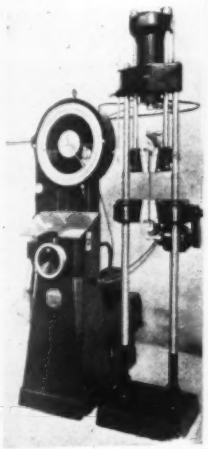
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

High-speed Production Wire Tester

For rapid production testing of wire (to 20,000 lbs.) this new instrument has a pendulum indicating unit (guaranteed accuracy ±0.5%) with three scale ranges: 0-2,000, 0-10,000 and 0-20,000 lbs. reading respectively in units of 5, 20 and 50 lbs. Gripping heads, entirely open to the front, permit speedy location of specimen in gripping jaws. Another refinement locates specimen in the center of the wedge grips. Loading speeds may be regulated in stepless intervals from zero to 8"/min.; return speed of the gripping head is 12"/min. Lower adjusting head has a separate motor drive, giving an adjusting speed of 10"/min. Distance between the gripping heads is zero to 36"/min. Apparatus is hydraulically driven. One handwheel controls the loading speed and the return of the upper gripping head. — *Riehle Div., Am. Machine & Metals Mfg. Corp., East Moline, Ill.*



Vacuum-tube Galvanometer

Named by reason of the similarity of its use with that of the familiar galvanometer, the Vacuum-Tube Galvanometer is a general-purpose instrument for use as a null indicator in all potentiometric measurements. A compact, self-contained unit adapted for measuring systems of high resistance (*e.g.* 10^{10} ohms) and those easily polarized, with the same simple technique and sensitivity (0.1 millivolt) as for all ordinary systems, the new vacuum-tube instrument may be used in conjunction with any type of potentiometer. Said to be simpler and more convenient in use than an ordinary galvanometer, it cannot be easily harmed by an untrained or careless operator, and is expected to replace ordinary galvanometers and also electrometers in a variety of applications. — *Hellige, Inc., 702 Northern Blvd., Long Island City, N. Y.*

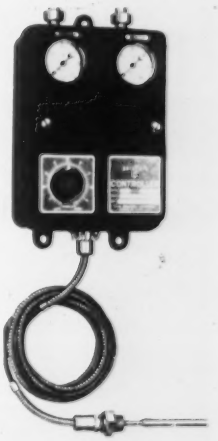
Photocell Control Outfit

New "Model 729" photoelectric control outfit, designed for difficult service conditions, is applicable to industrial control applications such as counting, sorting and weighing devices, processing control, safety cut-offs, alarm warnings, etc., in which interruption of a light beam provides the initial impulse for opening or closing an electrical circuit. It consists of a Weston photocell of high output characteristics in a protective

mounting, the complete relay unit in a separate panel box, and a light source of standard design. A light intensity of 100 foot-candles falling on the cell provides adequate energy for positive operation of the relay system in contrast to the 200 foot-candle level formerly required. Output capacity of the new relay is 500 watts, so that most installations can be handled directly. The relay is arranged for single-pole, double-throw operation, with an overall speed of response of 0.15 sec. Positive action of the relay at speeds <400 operations per minute permits automatic control of high-speed industrial processes for which the previous outfits were unapplicable. A microammeter indicates the level of illumination reaching the photocell. Both the initial sensitive relay and the secondary power relay are said to be of simpler and more rugged construction than in previous units. Mechanical improvements in mounting and case design, such as use of a threaded back for screw mounting of photocell, are said to make for simplicity in installation and maintenance. — *Weston Electrical Instrument Corp., 591 Frelinghuysen Ave., Newark, N. J.*

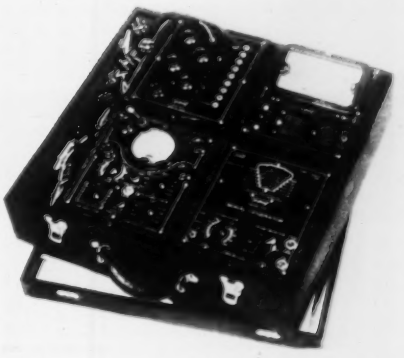
Air-operated Controller

Designated as the "Model 90 Controller" a new pneumatic-type controller for temperature, pressure and liquid level has been added to the maker's line, to take care of the many requirements for automatic temperature and pressure control that do not warrant a chart record of the controlled condition and also for applications where recording instruments already are in use. It is a small, compact instrument, said to be of simple construction and to embody late developments in automatic control. Principal feature of this controller is its measuring element, of the same type as those employed in maker's recording instruments. New controller is equipped with a wide-range sensitivity adjustment. It can be changed from direct to reverse acting, or vice versa, by the user without additional parts. The case is moisture-, fume-, and dust-proof and is offered in two forms for wall and for flush panel mounting. — *The Bristol Co., Waterbury, Conn.*



Portable Servicing Set

Said to be a complete servicing laboratory in portable form, new Model 1206 Master Unit Test Set comprises four separate units of interchangeable size: Model 1200 Volt-ohm-milliammeter unit; Model 1210-A Tube Tester; Model 1220-A Free Point Tester, and Model 1231 Direct-reading All-wave D. C. Signal Generator. Each is housed in a 7¾" × 6¾" × 4¾" metal case with black wrinkle finish. Panels are in matching silver and black. Model 1206 may be obtained complete, or units may be obtained separately. Leatherette carrying cases are available for one, two, three or four units. — *The Triplett Electrical Instrument Co., Bluffton, Ohio.*



BAILEY METER CONTROL SYSTEM

The Mark of

Effective Control

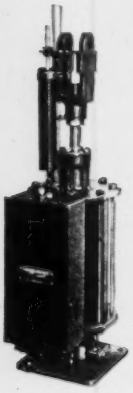
Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.



Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

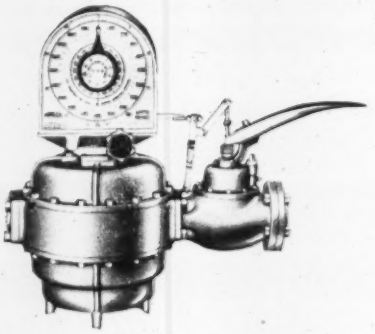
G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

Redesigned Liquid Meter and Volume-set Valve

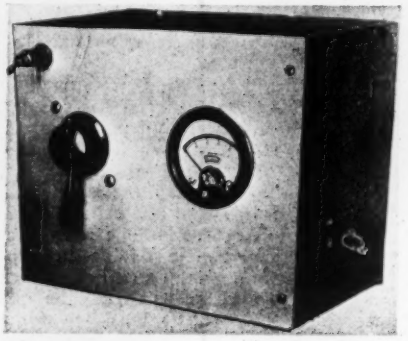
A new 2½" pipe size, 200-g.p.m. max. capacity "Xacto" quintuple-reciprocating-piston liquid meter is announced. Although its general design and princi-



ple of operation remain unchanged (see *Instruments*, Feb. 1933, pages 35-37) it embodies a number of construction refinements: new rotary valve minimizes friction and permits two cylinders to be filled simultaneously; piston leather packings provide for longitudinal rather than outward excess expansion and prevent binding and wobbling; speed has been increased and weight decreased; valve seats are of stainless steel and valves of close-specification bronze. Various forms of cyclometer and dial registers are available, as well as recording printers. Also announced is a new automatic predetermining dial and control valve (illustrated) said to be "ideal for use on tank trucks": one knob sets for quantity desired, delivery is automatic and a continuous counter records to 1,000,000 gallons and repeats, obviating need for multiple-compartment trucks and permitting one-man trucks.—*S. F. Bowser & Co., Inc., Fort Wayne, Ind.*

"Capacitrol"

Employing the principle of body capacity and designed for the control of automatic doors, alarms, signals, bells, the "Capacitrol" operates on the ap-



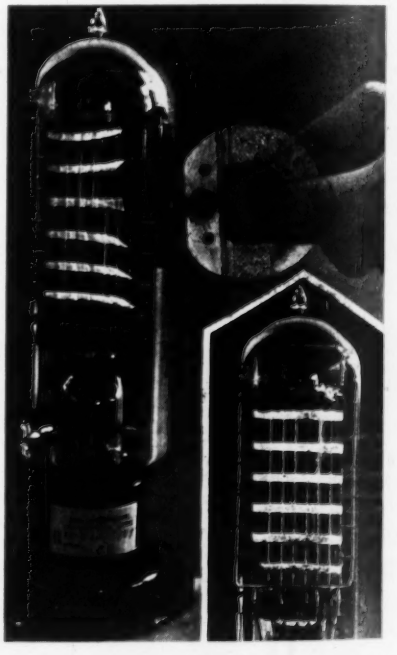
proach of a person or car to <3 ft. of its antenna, which may be from 5 to 50 ft. of rubber-covered wire. Thus the unit (5½" × 6½" × 8") may be installed at almost any convenient place and the antenna run to wherever it is desired the control point to be: overhead, along a wall, etc. Manufacturer states that this device is particularly useful in points where it is not practical to use photo-electric apparatus or the installation of "treads" is not possible.—*J. Thos. Rhamstine, 392 Beaubien St., Detroit, Mich.*

Electrical Test Cart for Industrial Plants

Under the designation of "Graphic Analyzer" there has now been made commercially available the portable (wheeled) industrial test set described in the article by William Barbour in our Aug. 1935 issue, page 212. As made up for sale, it presents an improved appearance, embodies various conveniences and can be connected rapidly, but its essential components remain the same: recording wattmeter with high-chart-speed attachment, indicating ammeter, indicating voltmeter, variable-ratio current and voltage transformers, phase transfer switches, leads, etc. All wiring is concealed. There is a compartment for charts, ink and accessories. When a test is completed, the leads are simply dropped into the lower tray and the cart is ready for use elsewhere.—*William Barbour, 312 Memorial Drive, Cambridge, Mass.*

Vacuum Triode With Fluorescent Plate

For experimental and demonstration work, a new Type WL787 triode has, on the side of its anode which faces the grid and filament, a coating of willemite



which fluoresces with a bright greenish glow at all points bombarded by the plate-current electrons. Result: a definite pattern of the grid on the plate, making visible the electronic effects of changes in grid and plate voltages, or of externally produced fields (see illustration). Overall length (10") and plate dimensions (approx. 1½" × 3") permit phenomena to be seen across a classroom. Base is 4-pin industrial type. Other details:

Filament potential	6 volts
Filament current	1.6 amps.
Filament type	oxide coated
Max. filament potential	6.3 volts
Max. plate potential	400 volts
Max. plate current	0.1 amp.
Max. grid potential	200 volts
Max. grid current	0.05 amp.
Approx. amp. factor	3

—*Westinghouse Lamp Co., Bloomfield, N. J.*

Pressure-measuring Tubes for Air Velocity Indicator

Two more auxiliary "jets" (combinations of flexible tubes and terminal fittings) are announced as available for attachment to the Boyle Velometer (a direct-reading anemometer of the tilting-vane type, see *Instruments*, July 1935, page 191; Dec. 1935, page 343). "Type 2480 Static Pressure Jet" is used to obtain direct readings of static pressure in ducts, plenum chambers or pipes, in inches of water column, either positive or vacuum readings being obtainable, depending on the side of the Velometer to which the jet is attached. "Type 2485 Total Pressure Jet" ends in an impact opening which, when pointed in the direction of the air stream in the duct, permits obtaining a reading of the sum of the static and velocity heads.—*Illinois Testing Laboratories, 142 W. Austin Ave., Chicago, Ill.*

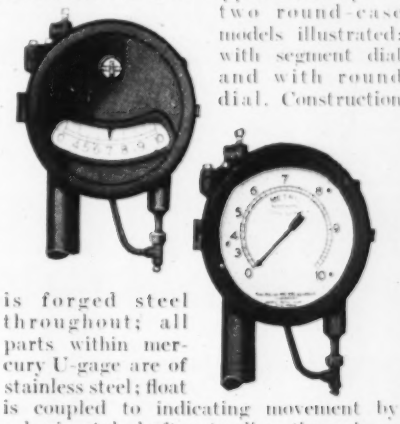
Kuder Direct-reading Colorimeter

Personal element in color evaluation is eliminated by use of a stable photocell, a calibrated galvanometer, compensatory means for light-source brightness and foreign particles on optical surfaces, etc., permitting the standardization of scales, each scale graduated directly in units of the unknown ingredient being determined. To date, nine such scales are available, all for the clinical field, but manufacturer's development staff is

standardizing numerous scales for industrial colorimetry. Concentration of sample being read directly, need of a set of standards of comparison is obviated. Light intensity and depth of solution to be analyzed being kept constant, and each scale being prepared from actual color-concentration curve for the particular substance and for the particular range, no errors are introduced by departures from Beer's law. Photometric sensitivity being 0.1% as against 1.6% for human eye at its best; overall photometric accuracy being <1%, and full-scale deflection being possible for >8% light attenuation, determinations can be made on "pale" solutions. (Each scale as supplied by manufacturer allows for full-scale deflection for desirable maximum reading of a particular substance in a particular line of work.) Instrument must be operated from a stable individual source of electric energy, preferably a 6-volt storage battery, no commercial power circuit being sufficiently stable. The one-piece fused Pyrex glass fluid cell is said to be another unique feature. Two cells are supplied with each instrument.—*Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.*

Redesigned Indicating Flowmeters

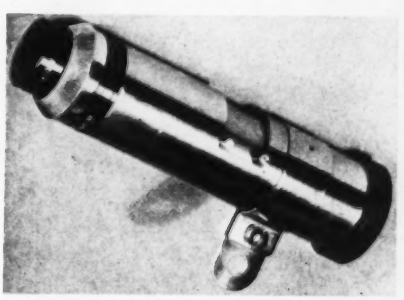
For indicating rate of flow of air, gas, oil, water or steam, manufacturer's line of fan-shape case mercury-and-float instruments has been supplemented by the two round-case models illustrated: with segment dial and with round dial. Construction



is forged steel throughout; all parts within mercury U-gage are of stainless steel; float is coupled to indicating movement by a horizontal shaft extending through an adjustable lapped stainless steel stuffing box. Four ranges (inches of water differential): 0-10, 0-20, 0-50 and 0-100.—*American Meter Co., 60 E. 42nd St., New York City.*

Instrument Panel Illuminator

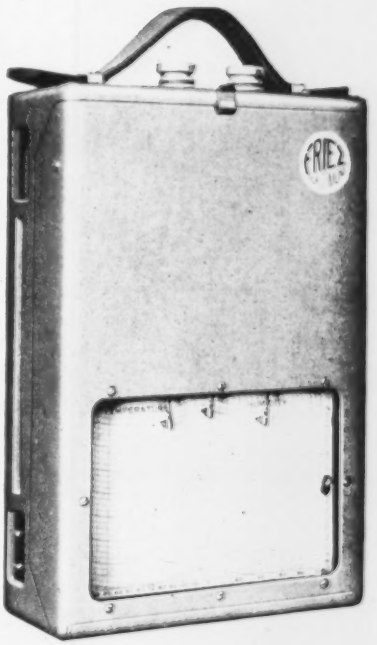
Designed for lighting instrument panels with controllable illumination at extremely low levels of intensity (as in aircraft where excess of light on panel or reflections in the windshield disturb the pilot's vision) the Fairchild Illuminator projects a light beam of practically uniform intensity throughout the field, which can be masked to any desired shape with no spill-over of stray light. By means of an adjustable diaphragm, light intensity is adjusted to match conditions of illumination outside the aircraft: during total darkness diaphragm is almost fully closed and effective illumination on panel is similar to faint moonlight—just sufficient to energize radium paint on instruments; during twilight or when approaching floodlighted



fields, a greater amount of light is permitted to pass. New device is provided with a shuttered opening in the side for map lighting or general cabin illumination. The size of opening is adjustable, to permit one pilot to fly the aircraft without discomfort while the other inspects maps or enters data on log sheets. Length, 3¾"; diam., ⅞"; miniature screw socket. Ordinary 2 or 3 c.p. miniature lamps provide satisfactory illumination for aircraft purposes.—*Fairchild Aerial Camera Corp., 62-10 Woodside Ave., Woodside, L. I., N. Y.*

FRIEZ BALTIMORE

On Record!



The value of records cannot be either disputed . . . . or computed . . . . In Air-Conditioning, either in industry or large scale comfort installations, a complete score of temperature . . . . humidity . . . . running time . . . . has become a necessity . . . . for engineering . . . . for sales . . . . for servicing. Compare all the Recording Instruments you have ever heard of . . . . the Friez Portable Recorder is the only one designed solely for all these specific purposes. It can be carried as easily as a camera . . . . its records are as accurate . . . . as legible as a photograph . . . . charts are of the size of filing cards and of the same shape. Temperature . . . . *Humidity . . . . Running Time . . . . a complete record on a portable, rugged recorder.

**Humidity is recorded directly without need of computations or tables.*

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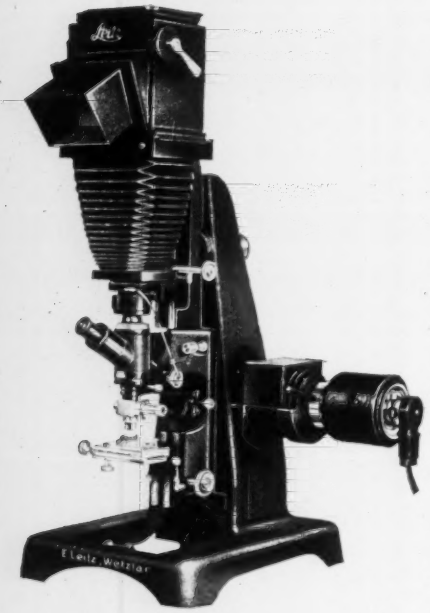
LEITZ PANPHOT

The Most Universal Equipment for Microscopic Research



Equally convenient for visual observation and photo-micrography.

Equipped with mirror reflex box to facilitate alignment and focusing for photography.

Usable also for micro-projection, drawing and photo-micrography in transmitted or reflected light.

The Leitz PANPHOT can be used for:

Brightfield (transmitted light)

Darkfield (from lowest to highest magnification including Planeton)

Reflected light (vertical illumination)

Ultropak illumination

Polarized light (reflected or transmitted)

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BRANCHES:
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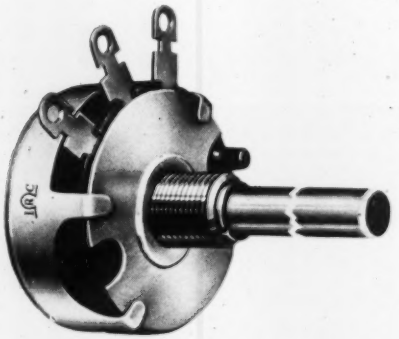
Variable Resistors

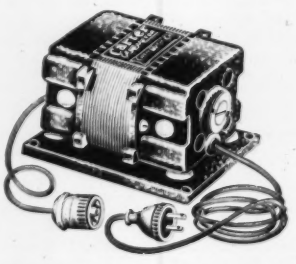
Among features of new "Type C Volume Control" are metallized type resistance coating permanently bonded to a moisture-proof Bakelite base; multi-



finger, silver-plated contacts; and an extremely hard coating and the "5-finger Spring Contactor," a combination which minimizes wear of element. Each silver-plated contact finger operates independently and makes contact in the same track with each rotation. Designed for use under severe atmospheric conditions, these new resistors makers assert undergo no appreciable change at 90% relative humidity and immersion of the element in water neither affects coating nor alters resistance values perceptibly. "Type C Volume Controls" are available either without switch or equipped with a low internal resistance switch. Provision has been made for two taps to be brought out anywhere on the element without obstructions in the path of the multi-finger slide contact.—*International Resistance Co., 401 N. Broad St., Philadelphia, Pa.*

Small Inverter

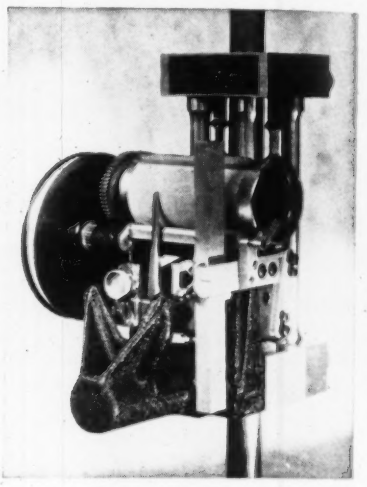
In districts where the only electricity supply is d.c., or in the field where only storage batteries are available, oscillographs and other apparatus requiring a small (<40-watt) supply of 110-volt a.c.



can be operated by means of the "Carter Converter" announced in 6 models: three are for 110-volt d.c. input and have 110-volt a.c. outputs of 5, 15 and 40 watts; three are for storage-battery inputs of 6, 12 and 32 volts and supply 30, 40 and 60 watts respectively of 110-volt a.c. Designed for continuous operation, new device has a dynamically balanced armature, a ventilated case, special bearings requiring no oiling, and rubber mounting to eliminate noise. Dimensions 5" × 4" × 2⅞". Weight 6¼ lbs.—*Carter Motor Co., 566 W. Superior St., Chicago, Ill.*

Polish Rod Dynamometer

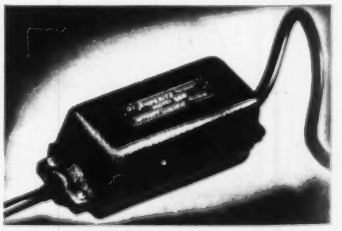
Designated as the "Dynagraph," [illegible] dynamometer for graphically recording instantaneous loads on polish rods of oil-well pumping equipment is self-contained and light enough to be handled by one man. There are no electrical or hydraulic parts. With polish rods of standard grades of steel, the record accuracy is ±2%. The dynamometer may be used above or below the cross-arm of the



reins. It usually is clamped onto the polish rod below the reins. In this case the stretch of the polish rod between the clamping points of the instrument is recorded (mag. 400×) on a chart which is rotated in proportion to the pumping stroke. If the dynamometer is clamped onto the polish rod above the cross-arm it is then in compression between the cross-arm and the polish rod clamp; the load is taken on four compression columns and the instrument records the strain in these columns. Clamping parts are arranged to take inserts, which may be secured for rods of ¾", ⅞", 1", 1⅛" and 1¼" diam. A convenient carrying case is supplied with the instrument.—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

Cable Type Transformer

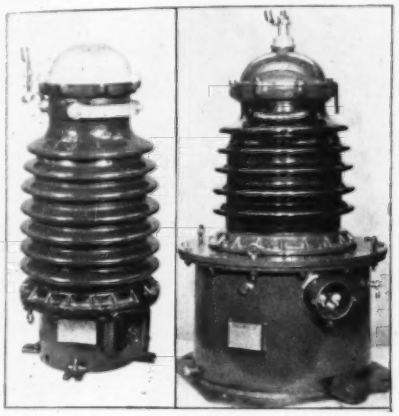
Designed to operate low-impedance microphones directly into amplifiers having high-impedance input, this new input transformer permits the cable of the



low-impedance microphone to be <2,000 ft. and makes high-gain amplifiers adaptable to any location. As many as four velocity microphones can be fed into one transformer. Hum pickup is said to be eliminated. Either a 50- or 200-ohm microphone can be fed into the standard input impedance of 200 ohms. Other impedances obtainable.—*Amperite Co., 561 Broadway, New York City.*

Instrument Transformers

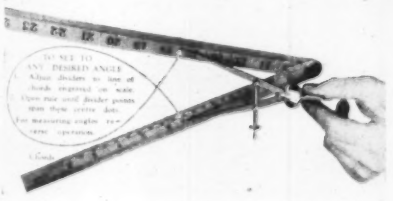
Several new lines of current and potential instrument transformers, in voltage ratings of 23 to 161 kv. and suitable for oil or Pyranol filling, have been announced. Sizes and weights have been reduced, and insulation factors increased. In the new *current transformers* the primaries are wound on porcelain spools, which serve as main part of insulation between primary and secondary circuits.



The 23- and 34.5-kv. transformers each have one porcelain-spool unit; for 46 kv. and above, each transformer has two or more porcelain-spool units connected in cascade. The current transformer element is mounted in a shallow base and extends up into a porcelain shell, which is used as the high-voltage bushing. The new *potential transformers*, designed for use only on 3-phase, 4-wire grounded systems, replace the single-bushing, conventional type. In voltage classes $\leq$69 kv., the units consist of a single core-and-coil assembly mounted in a shallow tank and extending up into a porcelain shell which serves as the high voltage bushing. In voltages $>$69 kv., the transformer consists of two or more core-and-coil units, mounted vertically and connected in cascade.—*General Electric Co., Schenectady, N. Y.*

Steel Rule and Protractor

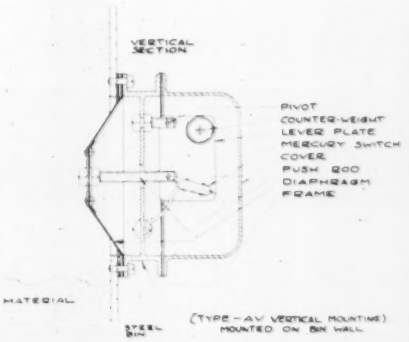
A jointed steel rule, made of stainless alloy, serves also as a protractor and can be set quickly to any desired angle. There is a line of chords engraved on one



side of the rule from 0° to 120°, advancing by half degrees, and the rule is also provided with two center dots (see illustration) one on each blade, by which, with the aid of a pair of dividers, the rule can be set to any desired angle or, conversely, any angle can be determined. Joint is provided with a spring tension which supplies sufficient friction to hold angle setting rigid for scribing and layout work.—*George Scherr Co., 128 Lafayette St., New York, N. Y.*

Bin Level Signal

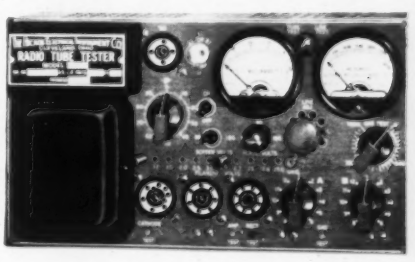
For nearly all forms of pulverized and granular materials, and for such applications as bins, conveyors, elevators, etc., this device, though just placed on the



market, is said to have had four years' service in the large cement plant where it was originated. It operates on the principle of lateral pressure displacing a diaphragm against a counterweight lever system and operating a mercury switch. This switch may operate a visual or an audible signal, or an automatic device for controlling the level, or both an alarm and a controller. Overall diam. 10¼"; projection 6½".—*The Bin-Dicator Co., 1615 E. Jefferson Ave., Detroit, Mich.*

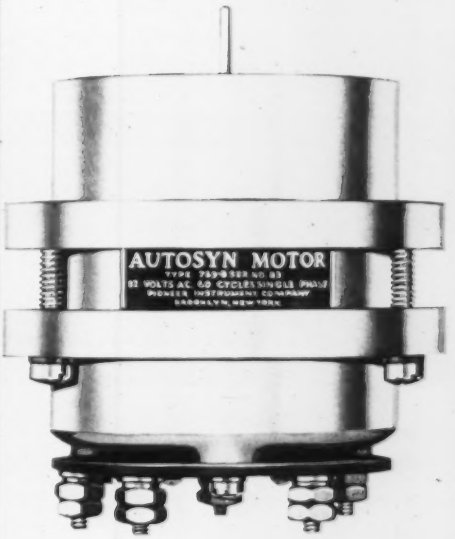
Dynamic Mutual Conductance Tube Tester

"Model AC47-A" represents latest development of testers embodying provisions for determining the dynamic mutual conductance of receiving tubes, as first advanced by maker in 1921. This is the ratio of change in plate current to change in grid voltage. Principle is to apply a.c. to the grid, superimposed upon the d.c. grid bias, and to read the a.c. com-



ponent in the plate current in the form of micromhos. Both this basic method and this new tester are said to have been approved by the manufacturers of radio tube and of receiving sets. In addition to this feature, the new instrument serves to test *separately:* (1) both sections of dual-purpose tubes, (2) both plates of rectifier tubes and (3) both plates of diodes. Gas content is indicated on a "good—bad" scale and also in terms of microamps. Cathode leakage can be measured. Insurance against obsolescence takes the form of 144 available switching combinations of which 48 are used for testing all present tubes, leaving 96 for future types.—*Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.*

"AUTOSYN
Self-Synchronizing Motor



TYPE 769B
ACTUAL SIZE

Type 769B, the smallest self-synchronizing motor manufactured, is suitable for a wide variety of remote indication applications. Slight movements of sensitive elements such as diaphragms and Bourdon tubes may be instantly and accurately transmitted to duplicate or triplicate indicators.

Size—2⅜" diameter x 2⅜" long
Weight—10 ounces
Current—.16 amperes
Voltage—32V. A.C.—60 cycle
Power consumption—2 Watts
Heat Rise—15°C.
Peak Torque—40 Gram. Cm.
Maximum lag—approximately 1½ Degrees
Shaft Diameter—1/16"
Ball Bearing Equipped

PIONEER INSTRUMENTS
Pioneer Instrument Company, Incorporated
BROOKLYN, NEW YORK
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ELECTRICAL THERMOMETER and TEMPERATURE RISE INDICATOR

Very useful for measuring temperatures by means of thermocouple, and for measuring temperature rise of motors and other electrical equipment.

Complete with calibrated thermocouple and 6 ft. lead wire. Range 0-60° C. $15.00

Other Ranges on application

GALVANOMETER RELAY No. 2566

Provides electrical contact 1, 2, 3, 4½, 9 or 13½ times per minute. Extreme sensitivity (⅛ microampere). Depressor bar action, with depressor bars periodically testing for position of pointer. Contact capacity 1 amp. at 110 volts A.C. Furnished in 4 coil resistances. Price $36.00 to $38.25.

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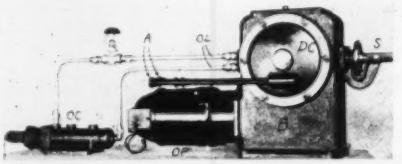
G-M LABORATORIES INC.
1732 Belmont Avenue, Chicago, Ill.

Self-contained, Self-powered Controller

For single industrial automatic control applications requiring modes of control obtainable only with the jet-pipe fluid-relay type of controller and oil cylinder type of power device, in plants unprovided with oil pressure systems, there has been brought out the "Askania Unit Regulator" which includes its own oil pressure system in the form of motor-



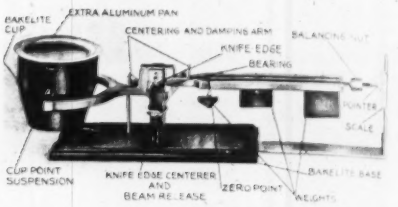
driven oil pump *OP*. (Hence our designation of "self-powered," since electric energy is available in all plants.) For pressure control applications the controller body *B* is provided with one diaphragm chamber *DC*; for ratio (differential-pressure) control the body is made with two such chambers, one on each side, each with a pressure connection *A*. In pressure control bodies the measuring spring and adjustable slider *S* oppose a single diaphragm; in ratio control bodies the adjustable pull of *S* determines the proportion. Under command of the controller through oil lines *OL* is the power device for operating valves or dampers: oil cylinder *OC* which has a max. stroke of 5" and a max. force of 100 lbs.—*Askania Regulator Co., 1063 S. Michigan Ave., Chicago, Ill.*

Self-operating Controllers

Improvements in maker's 30-year-old line of self-operating temperature and pressure controllers include an entirely new design of flexible seamless metal bellows, replacing the old series of capsules with soldered joints, and numerous minor refinements in design, materials and workmanship, making these new models suitable for industrial applications where the close control obtained with auxiliary power is not necessary, or where steam pressure available is <10 lbs./in.² which is minimum required for satisfactory operation of maker's Steam-operated Controller. Six temperature ranges, with min. of 100°F. and max. of 375°F., each range >75°F. Six pressure ranges: lowest 3-10 lbs./in.² and highest 70-100 lbs./in.² Valves are semi-balanced in sizes from ½" to 2". Max. pressure against which controllers can close valves is 125 lbs./in.². *C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

Portable Balance

The Bennett Balance brought out last year (see *Instruments*, Oct. 1935, page 280) has been improved along lines suggested by the New York City Dept. of



Weights & Measures, in order to meet the department's certification for use in drug stores and other fine weighing; and the improved model illustrated has been so certified. Its capacity is 100 g and its sensitivity 0.01 g. Being approx. 12" long and <1 lb. in weight, the improved model is still a "coat pocket" balance. Also announced are three accessories: a Bakelite carrying case; a table case of transparent non-flammable cellulose acetate; and an attachment for using the balance to determine specific gravities.—*Chemical Publishing Co. of N. Y., Inc., 175 Fifth Ave., N. Y. City.*

Pocket Oiler

For instrument departments, laboratories, etc., as well as home and office uses, the "Presto Positive deLuxe Oiler" is said to be "a real precision instru-

ment" and is a measuring instrument in that it delivers at each application a constant volume said to be "1/10 drop, no more, no less," and in that it has a scale showing the remaining supply. Constructed of Pyralin and chromium-plated brass.—*V. R. Hall Products Co., 7601 Amesbury Ave., Cleveland, Ohio.*

"Ultra-high-range" Resistor

Demand for a stable, ultra-high-range, non-inductive, high-voltage resistor is said to be met by two new resistors. (1) "Type FH-1" resembles the IRC metallized filament resistors, but it is said that

special processing serves to stabilize the unit against the effect of humidity and to reduce surface leakage. It is available in values <10,000 megohms for low-voltage applications. (2) Type "MG" units, for use at high voltages, are available in 3" to 12" lengths of glass with cast end terminals and special processing to control surface leakage. They are available in values from 20 megohms to 100,000 megohms and <4000 volts.—*International Resistance Co., 401 N. Broad St., Philadelphia, Pa.*

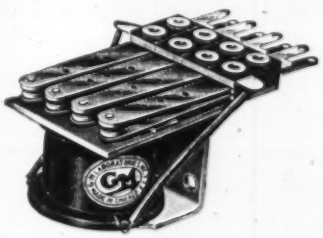
Low-pressure Test Gage

For indicating pressures <1.5 lbs./in.² where glass U-gages are ordinarily used, being guaranteed accurate to $\frac{1}{8}$" water column. Dial has double calibration:

0-35" and 0-20 oz./in.². Bronze diaphragm measuring element. Movement of "independent" type as specified for highest-grade "inspector's" gages. Black steel case, $2\frac{1}{2}$" diam., with nickel ring; $\frac{1}{4}$" pipe thread bottom connection. Supplied also with $2\frac{1}{4}$" × 5" × 6" aluminum carrying case containing also 3 ft. of connection hose. — *Fisher Governor Co., Marshalltown, Iowa.*

A-c. Relay

New "Type A" a-c. relay can be supplied for operation on voltages from 2 to 230 volts, 25 to 60 cycles, with up to four pairs of contacts, has a capacity of



10 amps. per contact, is said to be "the lowest cost relay on the market" by reason of extremely simple construction, which is said also to provide quiet operation. The coil is wound on a molded Bakelite bobbin.—*G-M Laboratories, Inc., 1735 Belmont Ave., Chicago, Ill.*

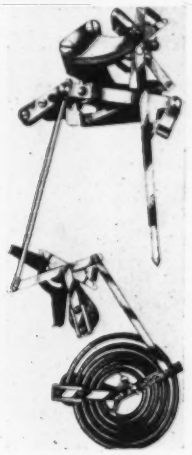
"Dwarf" Capacitors

Without impairing the durability of the metal-can electrolytic, it is said that a marked reduction in bulk for a given capacity is achieved in this new line of

dwarf units known as the GLS series: 1" diameter; heights from $2\frac{3}{16}$" to $4\frac{3}{8}$". Two voltage ratings: the GLS5 or 450 d-c. voltage, 525 surge peak, and the GLS250 or 250 d-c. voltage, 300 surge peak. Capacities 4, 8, 12 and 16 mfd. *Aerovox Corp., 70 Washington St., Brooklyn, N. Y.*

Pressure Compensator for Flowmeters

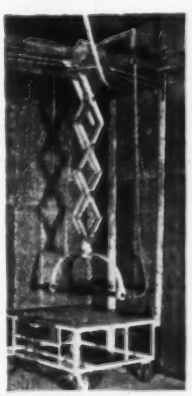
To compensate automatically for variations in line pressure of compressible fluids, which variations affect the readings of flowmeters operating on differ-



ential-head principle, the Foxboro Automatic Pressure Compensator has been developed for flowmeters of that make. It consists essentially of a spiral pressure spring responding to line pressure and through a transmitting lever adjusting the multiplication of the linkage between meter float and meter penarm. This is not an additive correction but a percentage correction, its linear amount being a function of the flow rate and being calibrated to fit the meter's flow formula. New device is sensitive to 0.1% change in line pressure and will correct position of flow pen for such a minimum change. On square-root flow scale meters, pen position is varied proportionately to change in absolute pressure; on uniform flow scale meters, pen position is varied proportionately to square root of change in absolute pressure. Should maximum flow and maximum pressure occur simultaneously, pen will not travel beyond upper chart limit. If at any time a pressure-compensating meter is changed over to a service where compensation is not required, attaching one screw on Compensator to the mounting post in the instrument causes the device to become inoperative. Inclusion of Compensator in a meter does not affect inclusion of pens for recording pressure of temperature.—*The Foxboro Co., 46 Neponset Ave., Foxboro, Mass.*

X-ray Lazy Tongs

For supporting and fixing the tube and leads in the desired position during the radiographing of castings, etc., in industrial x-ray work, there has been

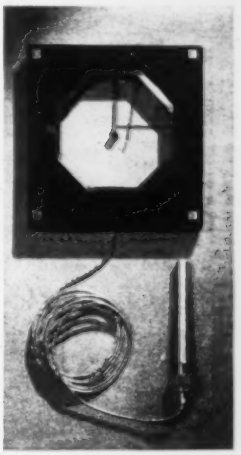


developed a system of support using "lazy tongs" constructed of kiln-dried maple and connected to a traveling crane of the same material through a joint which gives tongs 180° of freedom in a horizontal plane. Motions of tong mounting on cross member of crane, and of the cross member itself, are controlled through guide ropes and pulleys. Pantograph motion of tongs allows wide variation of heights for radiographic operations. *General Electric Co., Schenectady, N. Y.*

REPUBLIC RECORDING THERMOMETER

featuring a

"Cartridge Sealed" Helical Element



The New Republic Recording Thermometer (gas-filled type) introduces a helical element which is completely enclosed in a metal cartridge as a protection against dirt, moisture or damage by handling. The helical coil, capillary tubing and sensitive bulb are filled with nitrogen gas, calibrated and sealed, in the laboratory, to form a complete thermal unit.

•

This complete unit can be easily and quickly removed for recalibration, repair or change of temperature range, without disturbing or exposing any mechanism in the reading instrument.

•

Sensitivity, accuracy and trouble-free performance were stressed in this new design of thermometer, which fulfills all the requirements of modern industrial use.

•

The reading instrument may be placed at any distance, up to 200 feet, from the point of temperature measurement.

•

Evenly divided charts permit uniform closeness of readings throughout the entire range.

•

Combination records of temperature, flow, CO_2, draft, pressure, etc., may be obtained with multiple recorders.

Data Book 210, just published, gives complete description.

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REPUBLIC FLOW METERS CO.

2249 Diversey Parkway, Chicago, Ill.

Let us quote you on complete

METALLIC BELLOWS *assemblies*

Hydron metallic bellows are used as control elements in temperature and pressure control devices, and for liquid or gas seals on compressors and pumps. They are formed from one-piece, thin wall, metal tubing of the highest grade, expressly developed for this purpose.

The bellows have exceptional life characteristics due to the automatic testing of the tube wall in our original patented hydraulic forming process, and to the freedom from rubbing of frictional tool engagement with the thin metal wall during the formative operation.

Increasing numbers of manufacturers find it more economical and more satisfactory to have us supply the complete bellows assemblies. We have the equipment and they are pleased with the results. Let us quote you on complete bellows assemblies for your products.

We are primarily manufacturers of bellows and bellows assemblies rather than completed devices incorporating same, with the obvious intent of avoiding any competitive situation between ourselves and our customers. We do, however, produce to our customers' specifications complete devices involving our bellows.

Write for our catalogue

HYDRON

CLIFFORD MFG. CO.

564 East First Street Boston, Mass.

FACTORY REPRESENTATIVES

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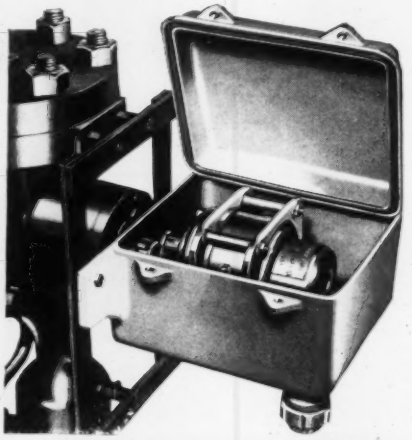
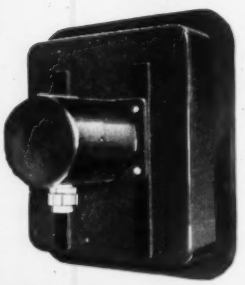
Franklin G. Slagel, 923 East 3rd St., Los Angeles
J. J. Shriver, 221 North La Salle St., Chicago

Liquid-level and Flow-rate Remote-reading Systems

"Heretofore definite limitations existed as regards flow and level instruments . . . In the case of level instruments" (reads manufacturer's announcement) "it was impossible to transmit to the main board any indications of level from float-actuated mechanisms except with high, medium and low signals." Telemetering



Above. Liquid-level telemetering transmitter.

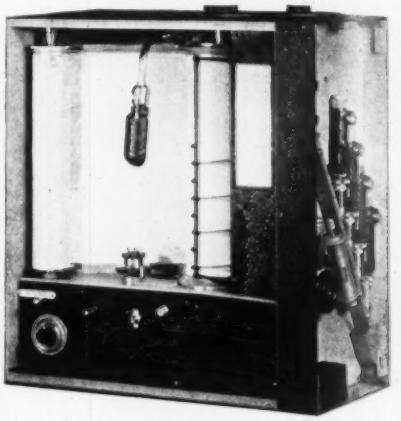


Right. Square-case receiving instrument. Rear view.

Below. Round-case liquid-level receiver.

system adopted by manufacturer consists of a pair of self-synchronous motors of standardized form such as have been used for years by other manufacturers for transmitting indications of float-actuated mechanisms steplessly and continuously (see *Instruments*, Dec. 1935, pages 329-332). What is unique, however, in newly-announced system, is manufacturer's use of radial magnetic coupling between float-actuated rotor and rotor of transmitting self-synchronous motor. This exclusive form of coupling (see *Instruments*, June 1933, page 109) is used for both the liquid-level and the flow-rate telemetering systems, and in both types of installations it obviates the need for stuffing boxes and makes possible perfect sealing. *C. J. Tagliabue Mfg. Co., Park and Nostrand Aves., Brooklyn, N. Y.*

● The Research Direct Pressure Engine Indicator



The Type V Indicator (above) is the accepted standard in the Diesel industry.

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A New Electrical Method of Geophysical Prospecting

By J. J. JAKOSKY
TECHNICAL DIRECTOR
and C. H. WILSON
MINING ENGINEER
International Geophysics, Los Angeles, California

THE Jakosky method of electrical mapping of oil structures is a modification of the resistivity method which operates on differences in electrical conductivity of geological strata, whereas other generally-used methods operate on differences of magnetic, gravimetric and seismic properties. It is applicable under fairly diverse geological conditions, permits obtaining subsurface information under conditions not favorable to other methods, and may be employed for rapid reconnaissance as in locating faults and fault zones. Dr. Jakosky's first official disclosure was made for the A.I.M.E. through its organ, Mining & Metallurgy, last May, and this article constitutes the first presentation outside the Institute.

EARLY work in the application of resistivity methods to placer mining and water-supply problems indicated that the effective depth range of these methods could be increased if certain factors could be properly evaluated or corrected. Even the simple conventional methods involving flow and measurement of current between two electrodes and measurement of potential between two additional electrodes (with the four electrodes arranged in a known configuration) may be employed for structural investigations where depth of penetration $<$200 to 300 ft., but beyond this depth the simple methods are subject to considerable error in interpretation. Research was initiated and a new electrical method developed which allows accurate and detailed mapping of structure at depths $<$4000 ft. During the past two years the method has been applied extensively in California under severe conditions. Numerous opportunities for checking its accuracy were present in the form of drilled wells or known subsurface geology. Hundreds of stations have been occupied and subsurface contours of certain horizons mapped. In addition, various straight-line traverses have been run for location of fault zones. Typical field results are given at the end of this article.

Our initial studies clearly indicated that the use of alternating current or of a periodically reversed direct current required careful determination of the strength, vector direction, phase relationship of current and potential, and contact resistance, before reliable interpretation could be made of the data to determine the subsurface. Obtaining these complete relationships of the a-c. phenomena necessitated detailed measurements and an involved instrumental technique. Furthermore, the time required for such measurements made field work relatively slow. Alternating current of pure sine wave-form was advantageous, but as the frequency was decreased in subsequent experiments bothersome polarization and other factors associated with the use of direct current were encountered. Commutated, periodically reversed direct current gave the greatest errors, attributable, to a large extent, to the steep wave front and irregular characteristics of the current pulses. Variations in contact resistance of the electrodes, commutator factors, inductive effects between power and potential leads, polarization phenomena and variations in current density, all contributed to the errors.

ACCURACY ESSENTIAL FOR STRUCTURAL MAPPING

The electrical resistance of sedimentary rocks may increase or decrease with the depth below the surface. Except where sharp lithologic changes or changes in ground water occur, resistances of the various strata comprising the geological column usually differ only to a relatively small degree as the depth below the surface exceeds 1000 ft. This is because of the compactness of the strata and the uniform impregnation of all strata with the deeper subsurface waters.

The strata seldom have a thickness exceeding a small fraction of their depth below the surface. This fact, together with the relatively small differences in electrical resistance, requires that the measurements made at the surface of the ground be reproducible and accurate to $<$0.2% for detail mapping of the subsurface beds. Conventional resistivity methods appear to be subject to errors of many times that amount, often $>$5%.

VARIATIONS IN RESISTIVITY CAUSED BY CHANGES IN CURRENT DENSITY

Generally, different values of resistance are obtained for different magnitudes of current flow.[1,2] Detailed measurements of various gouges and sedimentaries showed considerable changes in the apparent resistance with variations in current. Field work on these and similar materials "in place" showed that the resistivity sometimes increases and sometimes decreases with an increase in current (the electrodes remaining in fixed positions). These phenomena are probably associated with electrolytic and ionization effects, which in turn depend upon the nature of the electrolyte contained in the strata and the chemical characteristics of the gangue or sedimentary rock materials. These variations in apparent resistivity greatly affect conventional methods which employ any current density that will give a conveniently measurable potential for the particular spacing and electrode configuration used.

Duplicate measurements have shown (1) that such irregularities may obscure and sometimes entirely conceal the effects due to structural discontinuities in the earth, and (2) that these irregularities may be practically eliminated by maintaining a regular predetermined relationship in the values of either the potential or the current at successive regularly varied electrode spacings, in order to cause either the potential or the current to be varied in a regular and systematic manner.

VARIATIONS IN RESISTIVITY CAUSED BY POLARIZATION

From the viewpoint of physical chemistry, the earth may be considered as an almost nonconducting rock material impregnated with an electrolyte whose characteristics vary with different strata. An electric current flowing through such materials is subject to essentially

the same laws and reaction phenomena as govern the flow of electric current through any other electrolyte or galvanic cell. Such a cell is reversible if every substance composing it is in a stable state, and under these conditions a change in the applied external emf. will cause reactions which will be exactly reversed by the corresponding change in the applied emf. The relationship between potential and current flow through such a cell is almost linear, and the internal resistance of the cell can be determined over a fairly wide range of current flow. The resistance also remains constant regardless of the time during which the current flows. These are the conditions that prevail in a "reversible" cell.

When current is passed through the earth, however, certain chemical reactions or electrolytic effects take place whereby the system undergoes irreversible changes. Under such conditions a linear relationship does not exist between current and applied electromotive force, and the "resistance" will vary with the current density and with the time during which it flows. The more complex the electrolyte, the more pronounced are the polarization and electrolytic effects. Alternating current, and direct current with commutators for rapidly changing the direction of current flow, eliminate the reversible electrolytic effects, and tend to minimize but do not eliminate the "irreversible" effects. The abrupt changes in the depth-resistivity curves, so characteristic of present conventional "resistivity" methods, cannot possibly be due to the relatively small changes in actual resistance of the subsurface strata, and are caused largely by electrolytic phenomena. It must not be assumed that excessive current densities are required to produce these effects.

Certain errors in obtaining the true relative resistivity values may be eliminated or minimized by employing much greater flows of current in the energizing circuit during short periods of time. In other words, it is advantageous for accuracy of field work and interpretation to employ heavy current flows for energizing the earth, and medium-sensitive measuring instruments for studying the flow and the distribution of current in the subsurface.

As distinguished from previous electrical work, this method utilizes the creation of an electric disturbance of high intensity but relatively short duration[4] (usually <30 sec. and preferably <10 sec.) which produces in the earth a short-duration electromagnetic field impulse having electrical and magnetic components. Measurements of the magnetic field or of the potential values associated with the flow of current are ordinarily made at several points on the earth's surface.

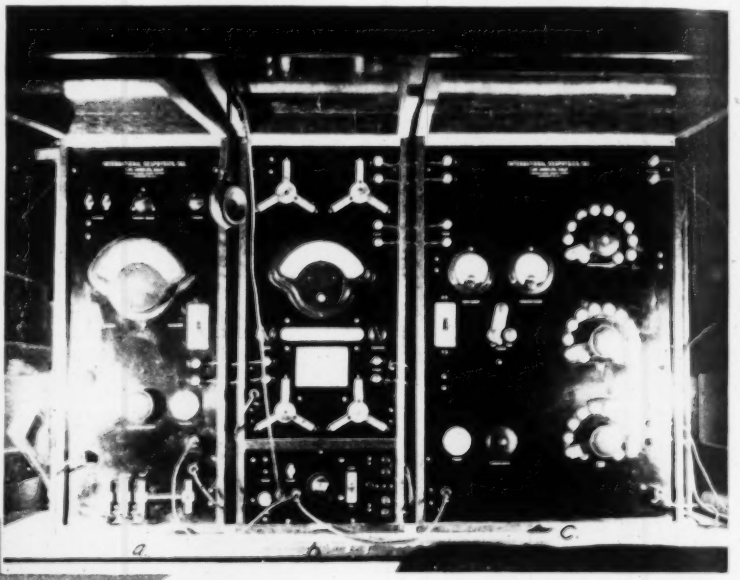

Fig. 1. Instruments for electrical geophysical measurements

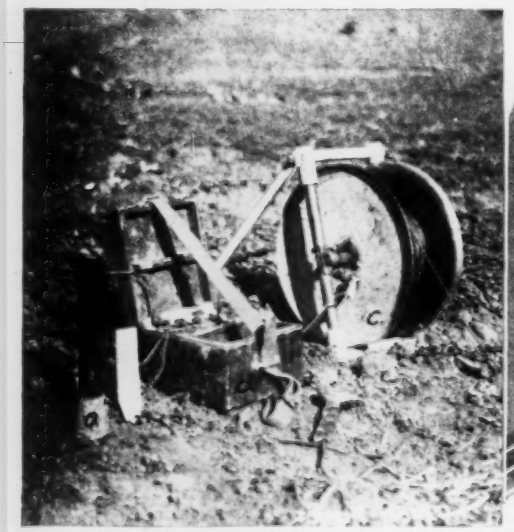

Fig. 3. Apparatus at end of field lines; electrical geophysical surface measurements.

Fig. 2. Instrument truck, showing high-voltage bushings for connecting external line wires.

The principle of maintaining a high current flow for a short period with medium-sensitive measuring apparatus may be illustrated by analogy: In the seismic method of prospecting, a high pressure or disturbance is created for a short time by use of dynamite. If the force of the explosive were to be spread out over a considerable period of time, the low-frequency wave would not be measurable at remote points by present types of recording or pickup seismometers. Sufficiently sensitive seismometers could be built, which would be capable of detecting such long-time waves as seismic or flexure waves, but they would not be practical because they would respond to parasitic tremors caused by wind, trucks, etc., and increased ground-roll effects.

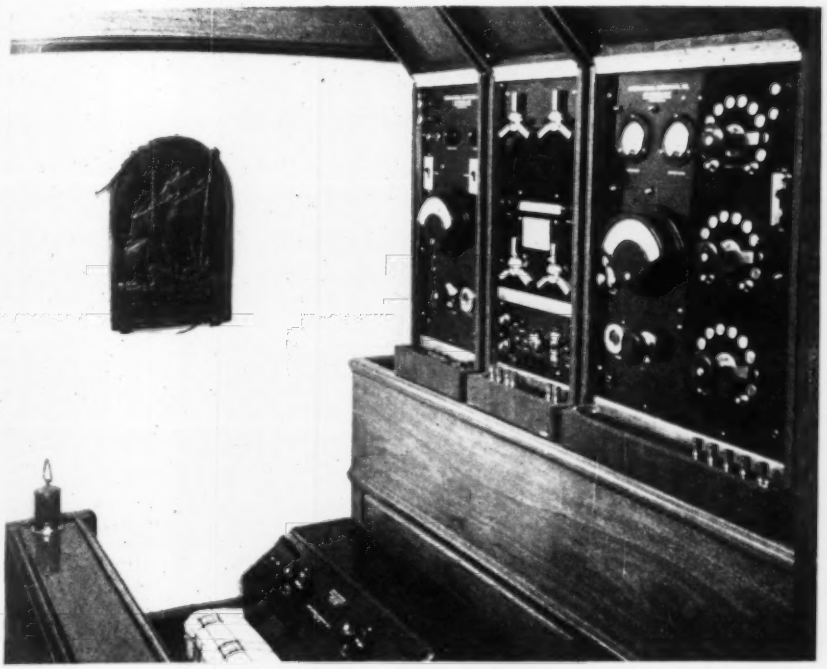

Fig. 4. Marine installation, showing apparatus used in geophysical work in offshore and submerged areas.

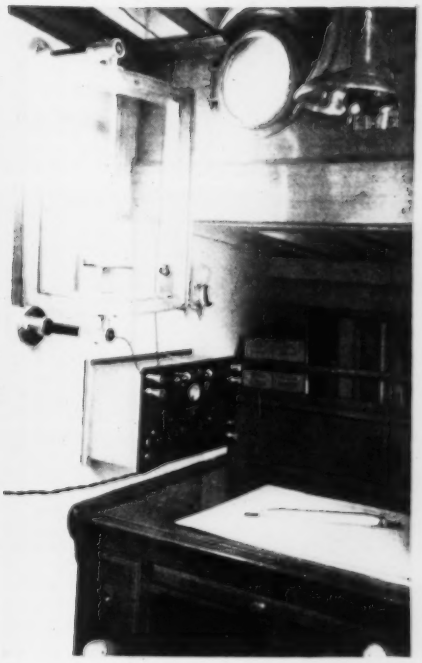

Fig. 5. Direction-finding apparatus for locations of stations in offshore geophysical work.

EQUIPMENT AND PERSONNEL

The essential apparatus consists (Fig. 1) of (*a*) apparatus for ground-potential neutralization and the control keys, (*b*) switching and potential-measuring apparatus, and (*c*) power-control panel. A telephone is provided (receiver shown suspended in upper center of the view) for communication with line men. The apparatus is mounted across the forward end of the truck body, on a table back of the driver's seat. The three panel boxes shown weigh approximately 600 lbs. Auxiliary equipment, such as reels and field lines, storage batteries, high-voltage generator, surveying instruments, and plane table, brings the total weight to approximately 2500 lbs.

Apparatus and equipment are carried in an enclosed two-ton truck, which is leveled at a place near the desired station, and then field reels are connected to the instruments by high-voltage bushings extending through the truck body as shown in Fig. 2. The outside ends of the lines are connected to their respective points of measurement, which have previously been surveyed and marked with numbered stakes. The instrument operator is then ready to carry out his measurements from within the truck.

Apparatus at the end of each field line (Fig. 3) consists of (*a*) low-resistance earth electrode, (*b*) telephone amplifier and ground-current-minimizing instrument, and (*c*) reel with 2000 ft. of special high-voltage insulated wire. Means are provided for connecting successive reels into the circuit as the work progresses and greater depths are involved. The numbered stake shown in the photograph between the electrode and the set box marks the point of measurement. The linemen are told by the instrument operator, *via* telephone, the stake number of the next point of measurement.

Field personnel varies with topography, brush, and other local conditions. Generally eleven men are used: one instrument operator, seven linemen, two surveyors, and the crew chief. The field data are calculated and plotted as the work progresses and interpretations are made shortly thereafter.

SUBSEA PROSPECTING

Electrical methods of this type are well suited for structural investigations of submerged areas. A view of the complete marine installation is shown in Fig. 4. The three panels shown in the upper part of the figure are similar in use to those in Fig. 1. In the lower portion of the figure is the continuous recorder employed for the "constant-depth" traverse described later.

Proper location for the points of measurements or stations when working over submerged areas is usually difficult. Especially is this true in swampy areas where surveying sights cannot be taken for any large distance. An excellent method for location of stations under such conditions by use of radio direction-finding equipment was developed. Two low-powered transmitting stations are set up on shore. The location of these stations is accurately determined and plotted on a base map. By means of the direction finder on the geophysical boat, rapid location of the stations is made by taking radio direction bearings on the two shore stations and plotting the bearings on the base map. Intersection of the bearings gives the point of measurement. Proper prior calibration of the equipment must have been made to correct for distortion of the radio wave front,[5] etc. The direction-finding apparatus is shown in Fig. 5.

INTERPRETATION OF FIELD DATA

Electrical geophysical literature on various methods of treating multi-layer problems to determine the depth of contact is fairly voluminous. Workers realize the mathematical impossibility of properly treating such problems. After considerable study by various mathematicians of our staff it was decided to base our analysis of the field data on a graphic method. In its simple form, the method consists in plotting the field data, after making proper corrections for topography, water tables, and changes in conductivity with depth, on semi-logarithmic sheets with the resistance values as abscissas (to a log scale) and the calculated depth of penetration as ordinates (to a linear scale). This results in a graphic record similar to the Schlumberger "electrical coring" or our dielectric impedance electrical logs obtained in

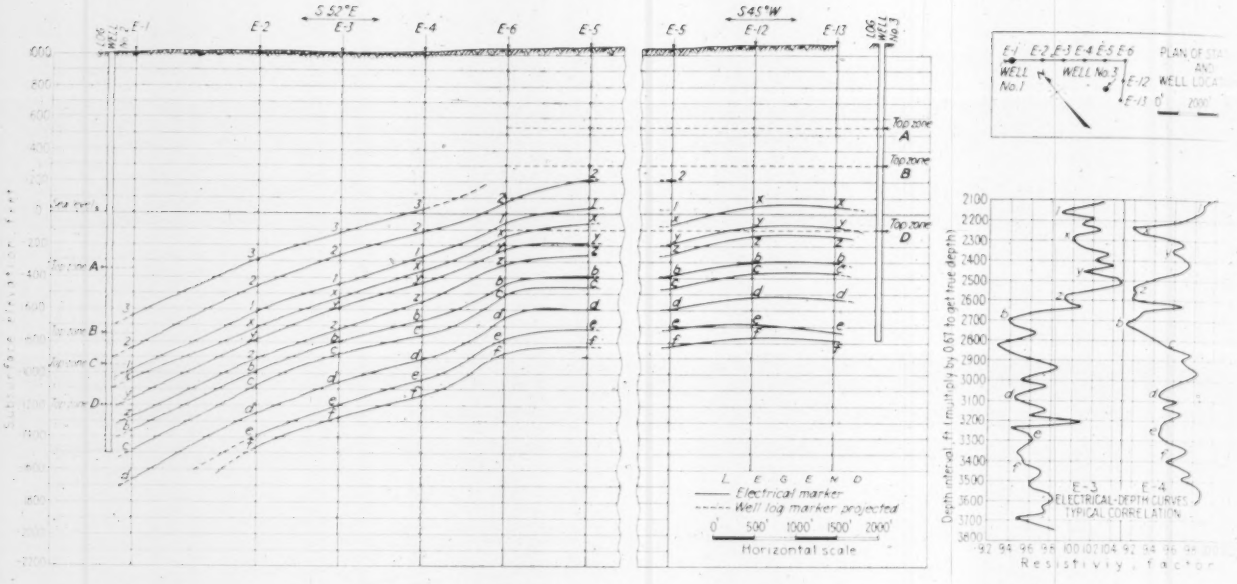

Fig. 6. Indicated structure profile through stations E-1, E-2, E-3, E-4, E-5, E-6, E-12, and E-13, Kern County, California.

wells." Analysis of the data from the various stations then proceeds in a manner similar to that employed in correlating electrical well logs for mapping the subsurface structure. Furthermore, the depth-resistivity curves obtained by our work may be correlated directly with the well logs; assuming, of course, that both the well log and the depth-resistivity curves are plotted to the same ordinate spacing. The measurements made at the surface of the ground will not contain the minute detail of the records made within the well but the major structural features or "breaks" will be present on the surface curves and may be correlated with the same breaks on the well curves.

Fig. 6 illustrates the general method of interpretation by use of the depth-resistivity curves. The electrical measurements were all made in a direction of S. 45° W., with the stations arranged as shown in the upper right-hand portion of the figure. The curves from stations *E-3* and *E-4* are shown in the right-hand portion of the figure. Corresponding points of inflection are labeled with the same letter, as shown. Correlation of the various stations gave the structural profile shown in the left-center portion of the figure. This work was conducted in Kern County, Calif., and the logs of subsequent drill holes are plotted on the profile. In this area the vertical changes in lithology are small and the geologic section is characterized by lens-shaped beds, with considerable variation in thickness. The sedimentary series here, being close to the source of deposition, shows considerable overlapping of the individual beds and formations, and in general is somewhat loosely consolidated and poorly sorted near the surface. Such an area provides a difficult proving ground for geophysical prospecting. The electrical method gave the necessary detail, and was able to provide an essentially accurate picture of subsurface structure.

When conducting electrical work of this type the stations are arranged to allow certain "phantom beds" or electrical horizons to be contoured throughout the area. The distance between stations must be such as will allow definite recognition of corresponding inflection points. This distance varies with local conditions and is dependent largely upon the continuity of horizons throughout the area.

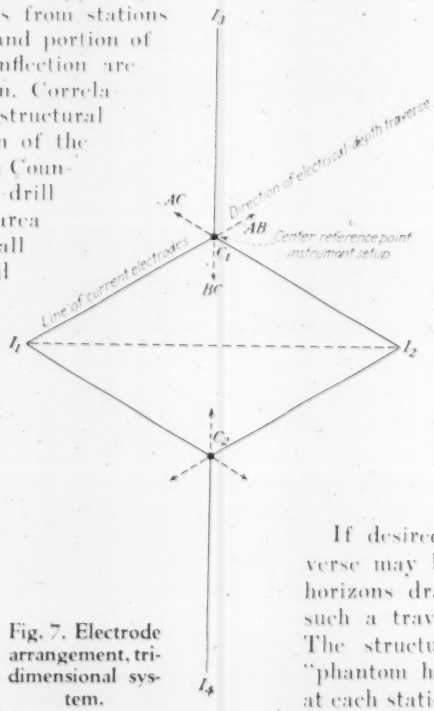

Fig. 7. Electrode arrangement, tri-dimensional system.

DETERMINING DIP AND STRIKE AT SINGLE STATION

An important feature of the development work was the evolution of a field procedure which allows the dip and strike of the various beds to be determined from a single electrical station. The measurements are usually made by the tri-directional system illustrated in Fig. 7. The three lines of measurement are laid out 120° apart, and current passed into the earth between electrodes I_1 and I_3; current is then passed between electrodes I_1 and I_2, and finally, current passed between I_2 and I_3. The points of measurement move progressively outward from the station center C as the depth of penetration is increased. By this arrangement the near-surface effects are properly evaluated, and suitable corrections are made for topography and the anisotropic properties of the strata. Various modifications of this procedure are evident, their choice being governed by local conditions. Analysis of the tri-directional system allows immediate determination of the dip and strike of the strata, and also indicates any changes in dip and strike due to thickening of beds or unconformities.

If desired, the dips along any particular traverse may be plotted and one or more phantom horizons drawn through them. Fig. 8 illustrates such a traverse using the tri-directional system. The structural trend, as shown by plotting a "phantom horizon" by use of the computed dips at each station, is in close agreement with the

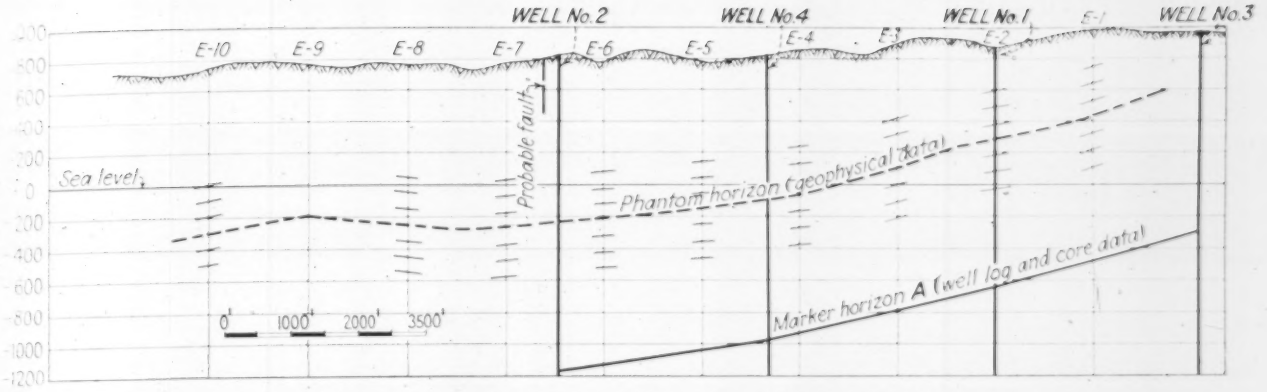

Fig. 8. Indicated structure profile through electrical stations E-1 to E-10, Bakerfield area.

shown by plotting the location of a lithologic marker encountered in three wells along the line of the geophysical traverse.

The tri-directional system is particularly suitable for reconnaissance work. It has been used, for instance, to determine the structural significance of magnetic "highs"; and to find whether certain magnetic anomalies in the San Joaquin valley of California are associated with changes in structural trends. Two or three tri-directional stations properly placed over such magnetic anomalies will give the required subsurface dip and strike. More detailed work may then be done in the areas of structural interest.

LOCATION OF FAULTS AND FAULT ZONES

Problems involving the location of buried contacts and faults are usually solved by some type of constant-depth traverse. In work of this type, measurements are made along a traverse which extends across the area where the fault or other discontinuity is expected. Faults and fault zones oftentimes are sharply indicated in this type of traverse since they are zones of better electrical conductivity. The material in the fault is broken or disturbed and contains a greater percentage of moisture than the original undisturbed sedimentary beds. This increase in moisture results in better electrical conductivity.

The constant-depth traverses may be of two types: (1) constant depth below the surface, or (2) constant stratigraphic depth. In the first type, the distance between electrodes is constant and such as to give the desired depth of penetration. In the second, the distance between electrodes is progressively changed as the traverse proceeds, in order gradually to change the depth of penetration and have it vary with the dip of the strata.

CONCLUSION

Two years of intensive application of the electrical method described have given ample opportunity to evaluate the effectiveness of the method. This work shows the method to be applicable under fairly wide geological conditions, but limited to those problems where the depths of penetration need not exceed 3500 to 4000 ft. The extreme detail obtained in normal field operation, with readings made at depth intervals of 15 to 20 ft., minimizes the possibility of errors in interpretation when working in areas of complicated stratigraphy. This method differs from prior electrical methods in maintaining an accuracy of measurement and interpretation consistent with the small changes in value introduced by the deeper subsurface stratigraphic changes, largely because of the following factors: (1) minimizing the variation in apparent resistivity with time of current flow, by means of a constant time of measurement; (2) eliminating the variation in apparent resistivity with density of current flow by systematically increasing the total current flowing in the energizing circuit as the volume of earth increases with greater depths of penetration; (3) development of a graphic method of interpretation, based primarily on the depth resistivity logs obtained from the surface measurements; and (4) multi-directional measurements, which allow evaluation of topographic and near-surface effects.

The method may be used as a supplement to other geophysical methods, and when operating as a constant depth traverse system, may be employed as a rapid reconnaissance method for indicating structural changes and for the location of faults and fault zones.

REFERENCES

[1] J. J. Jakosky, C. H. Wilson, and R. N. Anderson, "Electrical Properties of American Ores and Rocks," unpublished thesis, University of Utah, 1928.

[2] Karl Sundberg, "Effects of Impregnating Waters on Electrical Conductivity of Soils and Rocks," *Transactions A.I.M.E.*, Vol. 93, Geophysical Prospecting, 1932.

[3] J. J. Jakosky, Patents pending covering methods or apparatus or both.

[4] J. J. Jakosky, U. S. Patent No. 2,015,401, "Method for Determining Underground Structure," Sept. 24, 1935. Other patents pending.

[5] J. J. Jakosky, Operating Principles of Inductive Geophysical Processes, *Transactions A.I.M.E.*, Vol. 81, 1929, page 168.

[6] J. J. Jakosky, U. S. Patent No. 2,038,016, "Method and Apparatus for Alternating-current Investigation of Drill Holes," April 21, 1936.

Professor Herman Diederichs, author of the monumental work, Experimental Mechanical Engineering (of which Vol. I is on Engineering Instruments), has been elected dean of the College of Engineering, Cornell University.

Elmer A. Sperry, Jr., vice-president, Sperry Products, Inc., Brooklyn, N. Y., has been awarded an Edward Longstreth Medal by the Franklin Institute in recognition of his development of blind-flying instruments including the gyroscopic horizon, directional gyro, and automatic pilot.

For distinguished achievements in industrial management as a service to the community, Morris E. Leeds, president, Leeds & Northrup Co., Philadelphia, has been awarded the Henry Laurence Gantt Gold Medal. This medal is awarded annually by the Institute of Management, Research Group of the American Management Ass'n, to an individual selected by a committee of award, half of whom are appointed by the Institute and half by The American Society of Mechanical Engineers.

The Spencer Thermostat Co., Attleboro, Massachusetts, has inaugurated a new field demonstration service in the form of a complete line of "Klixon" thermostats, traveling by truck, paying visits to gas companies and gas appliance manufacturers throughout the country. Demonstrations of the thermostats in operation, and service and other helpful instructions are given to salesmen, engineers and service men.

INSTRUMENTS' BOOK SHELF

Handbook of Meteorological Instruments (Handbuch der Meteorologischen Instrumente und Ihrer Auswertung). By E. Kleinschmidt. Julius Springer, Berlin, 1935. $6\frac{3}{4}$x$10\frac{1}{8}$ inches. 733 + xv pages. Price, paper, 69 RM; cloth, 72 RM.

Prepared by twelve German meteorologists and scientists including the editor, Dr. E. Kleinschmidt, this handbook is a comprehensive source of information on all types of meteorological instruments and associated equipment. It is divided into ten sections on the measurement of the following elements: Temperature (56), Radiation from sun and sky (141), Humidity and evaporation (59), Condensation nuclei and precipitation (40), Atmospheric pressure (43), Wind (6.), Upper air exploration (207), Atmospheric electricity (62), Atmospheric optics and acoustics (49), Tables (6). The numbers in parentheses are the number of pages devoted to the subject. A good index is included. There are 463 illustrations.

The section on upper air exploration takes up 28 percent of the book, which bulk is evidence of the rapidly growing interest and activity of meteorologists and physicists in studying air masses, cosmic rays and other phenomena. An outline of this section will give a picture of the fine arrangement of the subject matter and the thoroughness with which each topic is covered. The treatment of the various subjects, despite the diversity of authorship, is quite even, which is a tribute to the quality of the editorship

This section opens with a description of the various forms of the commonly used meteorographs. Except for the old Marvin instrument, only European instruments are described. A method of testing meteorographs is outlined. The reviewer believes that the method is open to considerable improvement. It appears preferable and is just as practical to test the thermograph of the meteorograph in an air bath cooled by solid carbon dioxide (dry ice) instead of immersing the instrument in a liquid bath cooled similarly. Further, it also is necessary to determine the effect of temperature on the barograph element for the pressure range of the instrument, instead of only at atmospheric pressure as outlined in the handbook. The procedure of evaluating a meteorograph flight trace is given in extended detail, including an exposition on the derived curves useful to the meteorologist. The subject of sounding and pilot balloons is fully discussed, including history, construction, design, theory governing their use (such as the maximum height which can be attained, rate of ascent, etc.), instructions for operating, and functions in aerology. Various forms of theodolites for following balloons are adequately covered. Kites, including captive balloons on land and sea, are discussed in extended detail from every viewpoint of interest to a meteorologist. The use of airplanes to secure aerological data—a method extensively used in this country—is treated in detail, even to the extent of mentioning relatively impractical gadgets such as measuring air pressure by measuring the boiling point of water during flight. In view of present interest in radio meteorographs, the chapter on this subject should be useful, especially the description of the basic forms of the instruments. The radio meteorographs described, even though published in 1935, are rapidly becoming obsolescent, since development work is progressing rapidly both here and abroad. A chapter on methods and apparatus for observing and photographing clouds closes the section.

The section outlined in the preceding paragraph is quite representative of the treatment of the other instruments and apparatus. In most cases the historical steps in the development of a given device are briefly given. References to the original sources are plentifully scattered through the handbook. As has been hinted above, some criticism might be made as to the lack of critical judgment in the selection of the material. To a limited extent the handbook appears to be like a newspaper, giving all of the news, without always distinguishing between permanent and transient value. This procedure however has its advantages in that a number of devices are brought to the reader's attention, enabling him to secure a broad background in any field in which he may become interested, provided that he is not misled by the method of presentation. In extenuation of the failure to be highly critical, devices which were impractical years ago may be of considerable value today owing to the development of a new material or a new condition of use. An outstanding example of the latter is the radio meteorograph which is an outgrowth of the electrometeorograph which was developed in the 1870's and which was never very useful.

The handbook is an outstanding compilation and should be accessible to all meteorologists and scientists interested in the study of the upper air. The fact that the material covers European (mainly German) developments almost exclusively does not seriously detract from its value. The dissimilarity in our own and European practice is a stimulant, leading to improvement where our own is inferior and to a feeling of satisfaction where our own is superior. W. G. Brombacher (12.2)-B-

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Electrical Engineering in Radiology. By L. G. H. Sarsfield. Instruments Publishing Company, Pittsburgh, 1936. Cloth, $5\frac{1}{2}$x$8\frac{3}{4}$ inches, 276 pages. Price $6.00 postpaid.

The volume of business involved in the manufacture of medical and industrial X-ray apparatus in late years is considerable, and has justified the maintenance of active research and development laboratories by a number of concerns. These have put on the market an extensive and diversified array of X-ray tubes, rectifiers, transformers, voltage regulators, condensers, cables, control gear, etc. While books on X-ray radiology, radiography and diffraction have explained the fundamental principles of this art, they have had space for no extensive discussion of the requisite equipment. Thus there is a definite place in the world for a book dealing, as this one does, with the design, testing, operation and maintenance of these devices. The author is well equipped to write authoritatively, as he has had a number of years' experience in the radiological research laboratory at Woolwich. He discusses a number of tests and experiments he has made and includes some detailed designs of transformers that he has built. He is familiar with apparatus manufactured on the continent and in America and has not limited the book to British apparatus.

Most of the book is presented in a common-sense fashion easily understood by anyone, only a relatively small portion of the book requiring familiarity with the more technical concepts in electrical engineering.

Research laboratories will find particularly useful the full discussion of voltage-multiplying circuits and constant-potential circuits, the data on designs of high-voltage transformers, filament transformers and bushings for high-voltage insulation, and the discussions of operating characteristics. There are numerous references to the literature for more detailed accounts.

C. S. Barrett (7.8)-B-

Color Measurement. Theoretical Foundations and Applications (Farbmessungen. Theoretische Grundlagen und Anwendungen). By Eduard Hascheck and Max Hattinger. Emil Haim and Co., Vienna, 1936. Paper, $6\frac{3}{4}$x$9\frac{1}{2}$ inches, 89 pages. Price, 6S.10.50.

The more general application of color measurement and specification based upon spectrophotometric analysis has been somewhat handicapped by the absence of some single book in which the whole subject is treated. This book aims to fill this demand in that the treatment gives not only the details of the actual colorimetric standards set up by the International Committee on Illumination in 1931, but also the fundamentals of the Young-Helmholtz Theory on which the system is based. Original papers dealing with this subject appearing in the various periodicals must of necessity assume that the reader is familiar with the fundamentals, which may not always be the case.

Following a thorough theoretical discussion, the details of the I.C.I. System are given. Some space is devoted to the methods to be used for the reduction of the data obtained on several types of European colorimeters to the I.C.I. specifications. The latter part of the book is devoted to applications of colorimetry to various fields: medicine, metallurgy, chemistry and meteorology.

Tables of the I.C.I. Colorimetric Standards, and numerous interesting tables of the colorimetric properties of many chemicals, minerals, colorimetric indicators, etc., complete the book.

Joseph Razek (7.2)-B-

Radio Receiving and Television Tubes (third edition). By James A. Moyer & John F. Wostrel. McGraw-Hill Book Co., New York, 1936. Cloth, $5\frac{1}{2}$x$8\frac{1}{4}$ inches, xii+635 pages. Price $4.00.

When the previous edition was published—state the authors in their preface—"radio receiving tubes then in practical use had only two, three or four elements. With the . . . introduction . . . of tubes with five, six, or more elements, combining in one tube the functions that were formerly performed by two or more tubes, there were made available to the designer opportunities for obtaining results in radio reception that previously were economically impossible." They also refer to the new metal tubes and state that emphasis has been given to the strictly modern types of tubes and their radio, television and industrial plant applications.

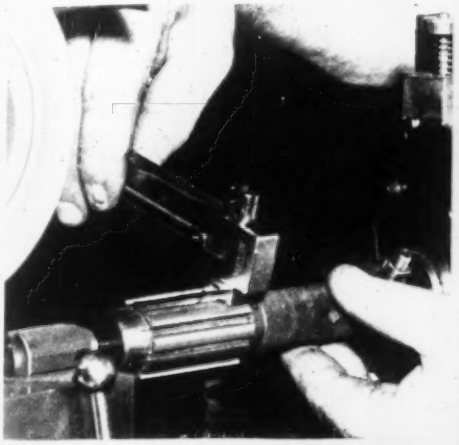
This statement is borne out by the contents of this book (which has been entirely rewritten and reset). At the end of the preface individuals, periodicals and organizations are credited with assisting in the preparation of the revision. Wherefore it is all the more disappointing to find evidences that the preparation has been slipshod in spots. For example this statement under the heading of gaseous industrial tubes: "In its commercial form it has many names, such as the grid-glow tube of the General Electric Co., the thyratron of the Westinghouse electric and Manufacturing Co., and so on." Surely the authors know that "Thyratron" is the G-E designation and "grid-glow" that of Westinghouse, and surely, instead of their tantalizing "and so on," they might have cited others, if only to be consistent, for elsewhere they give elaborate tables of characteristics and name the manufacturers of numerous devices. Again, in describing the operation of an automatic frequency-control arrangement (page 575) they state, "the speed of the disk is such that . . . the time of governor correction bears a definite proportion to the error in frequency regulation" although it is obvious from the context (there is no illustration) that the *shape*, not the *speed*, of the disk is what is supposed to prevent hunting. Toward the beginning of their elementary principles introduction (page 2) they refer twice in five lines to electrons being "evaporated" from heated filaments, although they know better—as they prove on pages 93-95 where they touch upon thermionic emission, secondary emission and plate current. Again on page 36, under the heading of "Power and Energy" we find the statement, "Electrical energy is measured by an instrument called the integrating *wattmeter*" (italics as in book), which should read: ". . . measured by an *integrating* instrument called *watthour meter* . . ." in order to be consistent with the preceding discussion of power, and in order to be correct.

In spite of a sprinkling of such annoying slips, nevertheless, the book deserves to be recommended as a fairly thorough and up-to-the-minute [illegible]

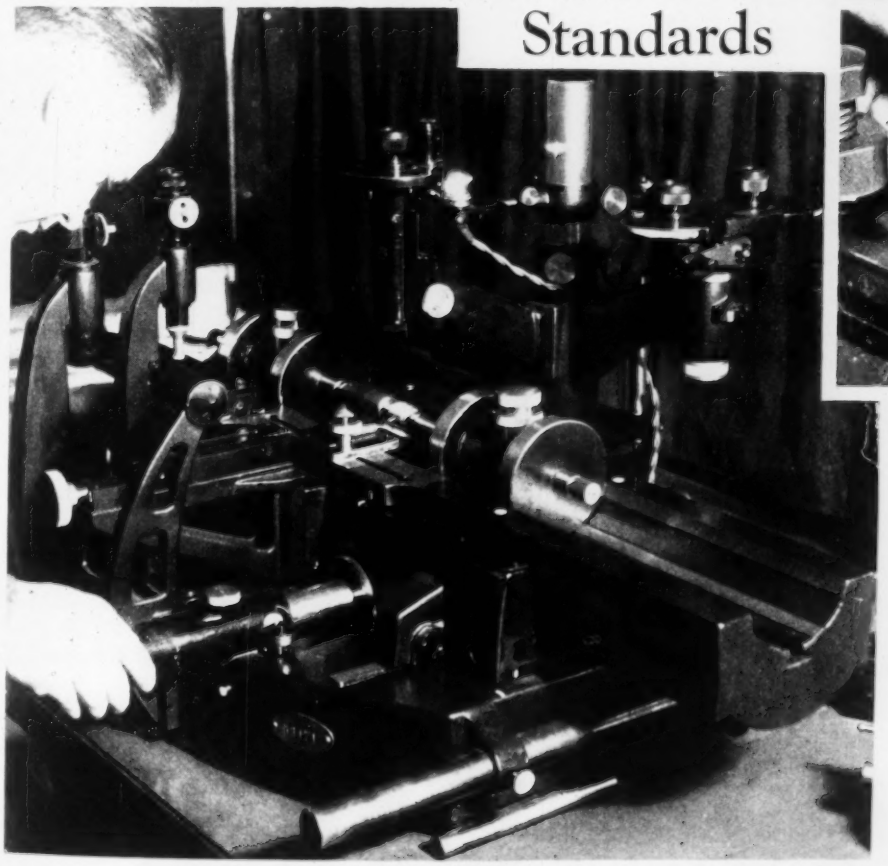
Continued on page 48

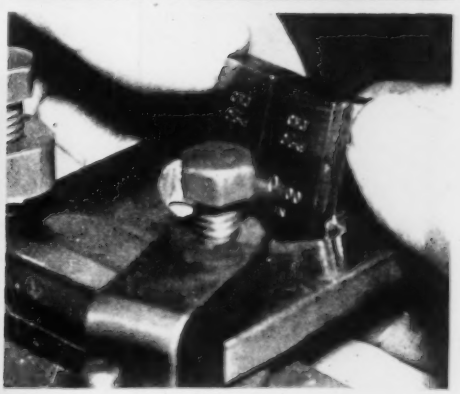
Inspecting Parts at Ford Plant

A Pictorial Article especially prepared for publication in *Instruments*



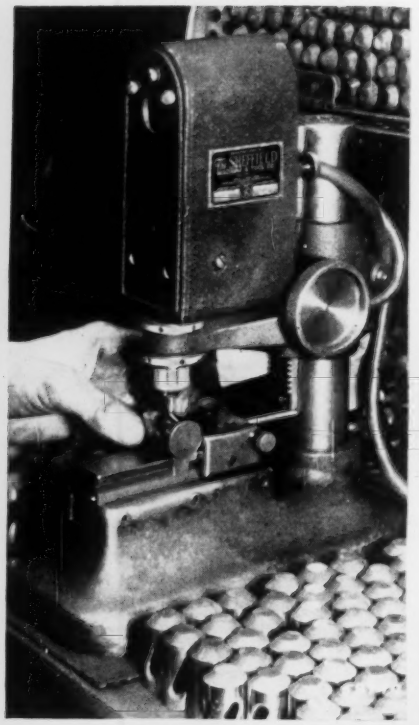
1. The Use of Standards

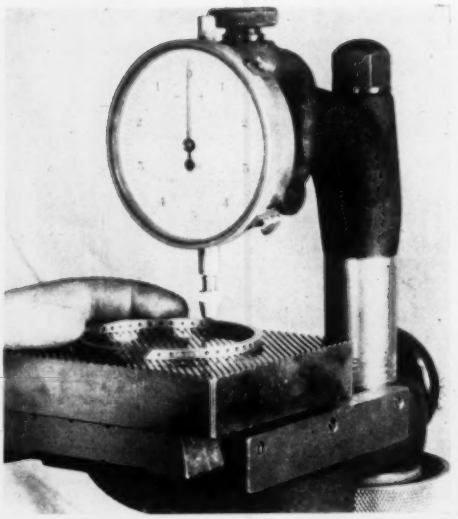


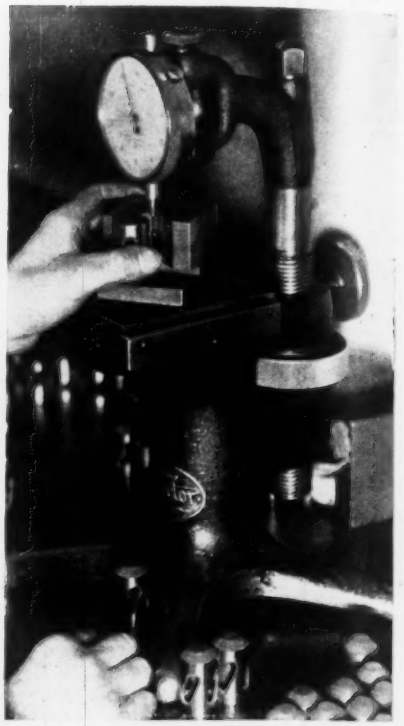


Johansson gage blocks are widely used for checking and setting the gages actually used for parts inspection. *Upper left*—With two Johansson blocks, the jaws of a spline gage are precision spaced. *Upper right*—One of the twenty-four gage checkers using a set of three blocks to verify the high and low limits of snap gages. *Mid-left*—Setting an internal indicator. *Mid-right*—Checking a snap gage on a grinder.

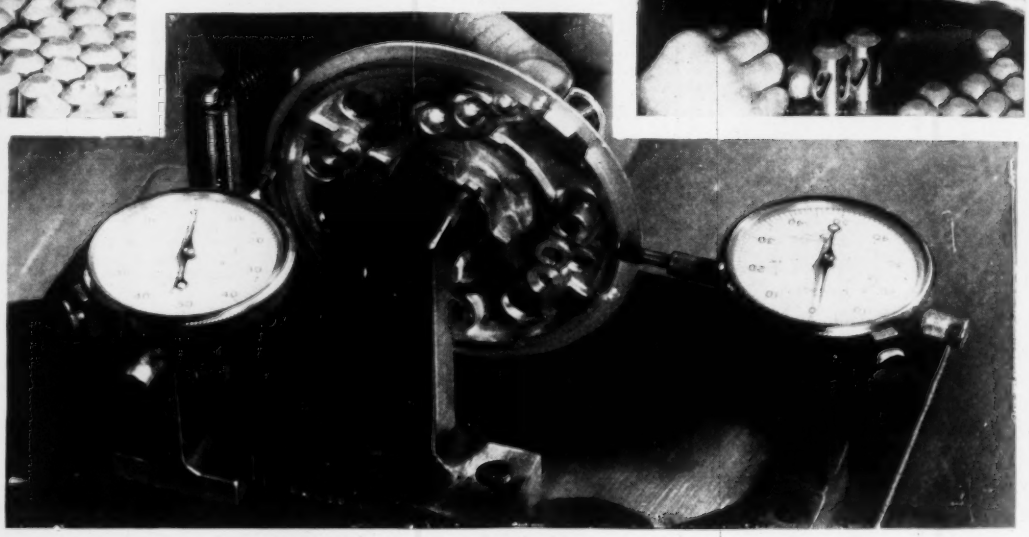
Lower left—Checking angle, pitch, diameter and lead of a thread gage by an improved optical method.



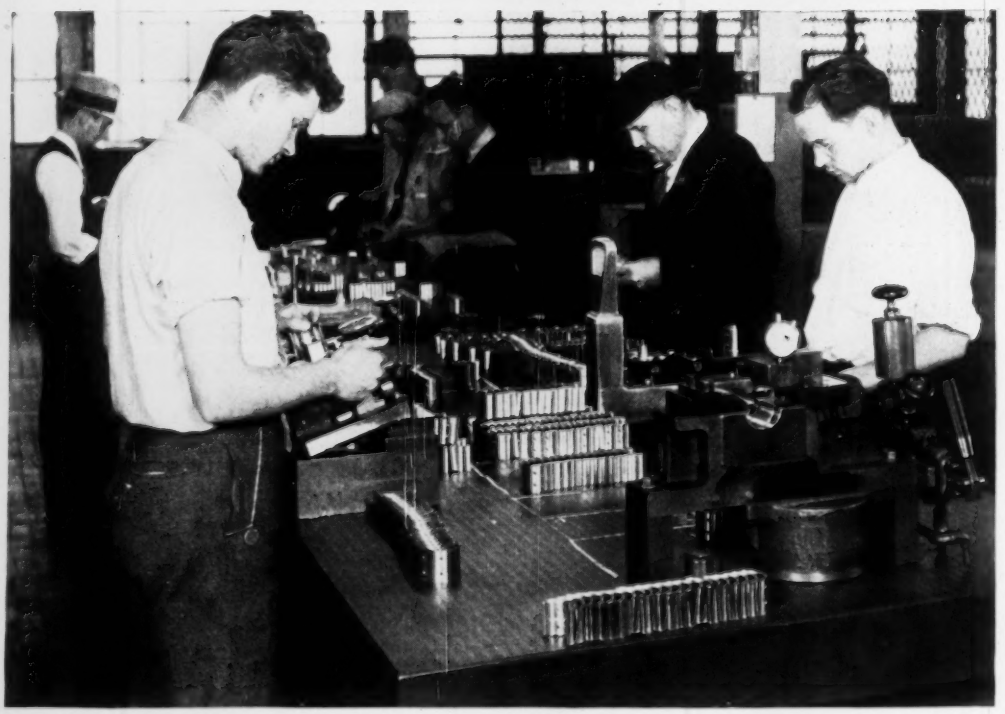




2. Indicators

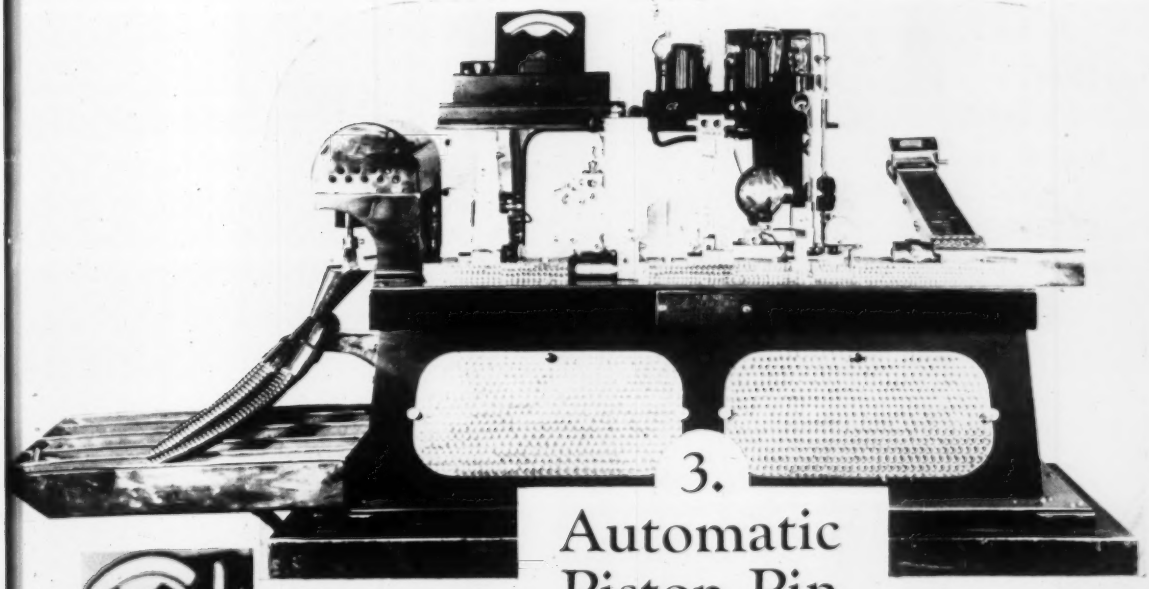


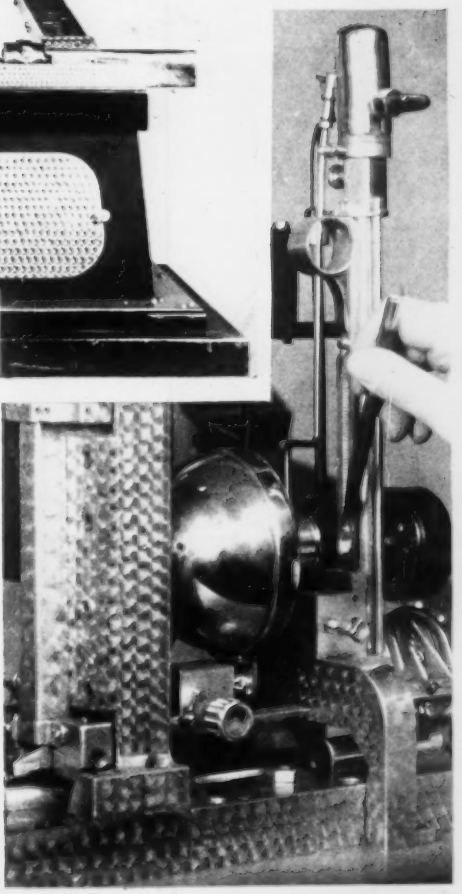
Upper left — "Go" and "no-go" signaling gage checking diameter of valve lifter. *Upper center* — Checking width of oil-control ring. *Upper right* — Checking length of valve lifter. *At right* —Inspecting generator end plate for concentricity: right-hand gage checks flange while left-hand gage checks bushing for parallelism.

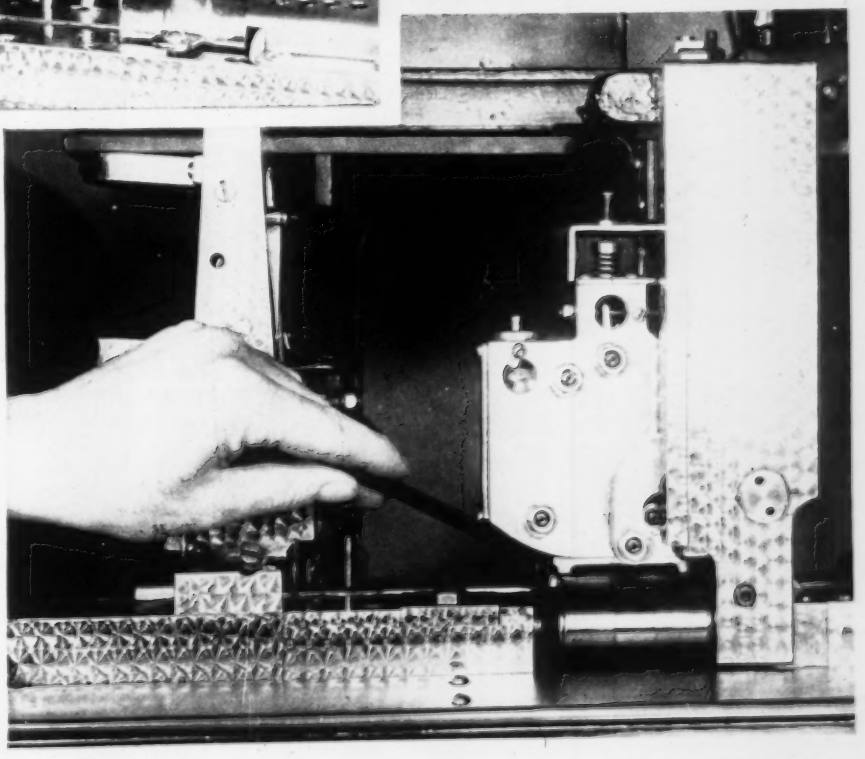


At left — Inspection of connecting-rod bearings is carried on by this group of operators, using highly specialized indicators. For example, the device in the foreground checks the bearings for diameter under conditions simulating those of actual installation; it has a special fixture utilizing compressed air to hold the bearing in place.

3. Automatic Piston Pin Inspector







Top—General view of the Ford-designed and built automatic inspector which checks piston pins (at the rate of 1500 per hour) for smoothness, hardness, straightness, roundness and diameter.

Above—First station, where pins, after being automatically cleaned, slide under the needle of an "acoustic" pick-up head. A two-stage audio-amplifier permits the detection of microscopic variations in surface finish, and a relay trips a rejection device if the pin is not "perfectly" smooth.

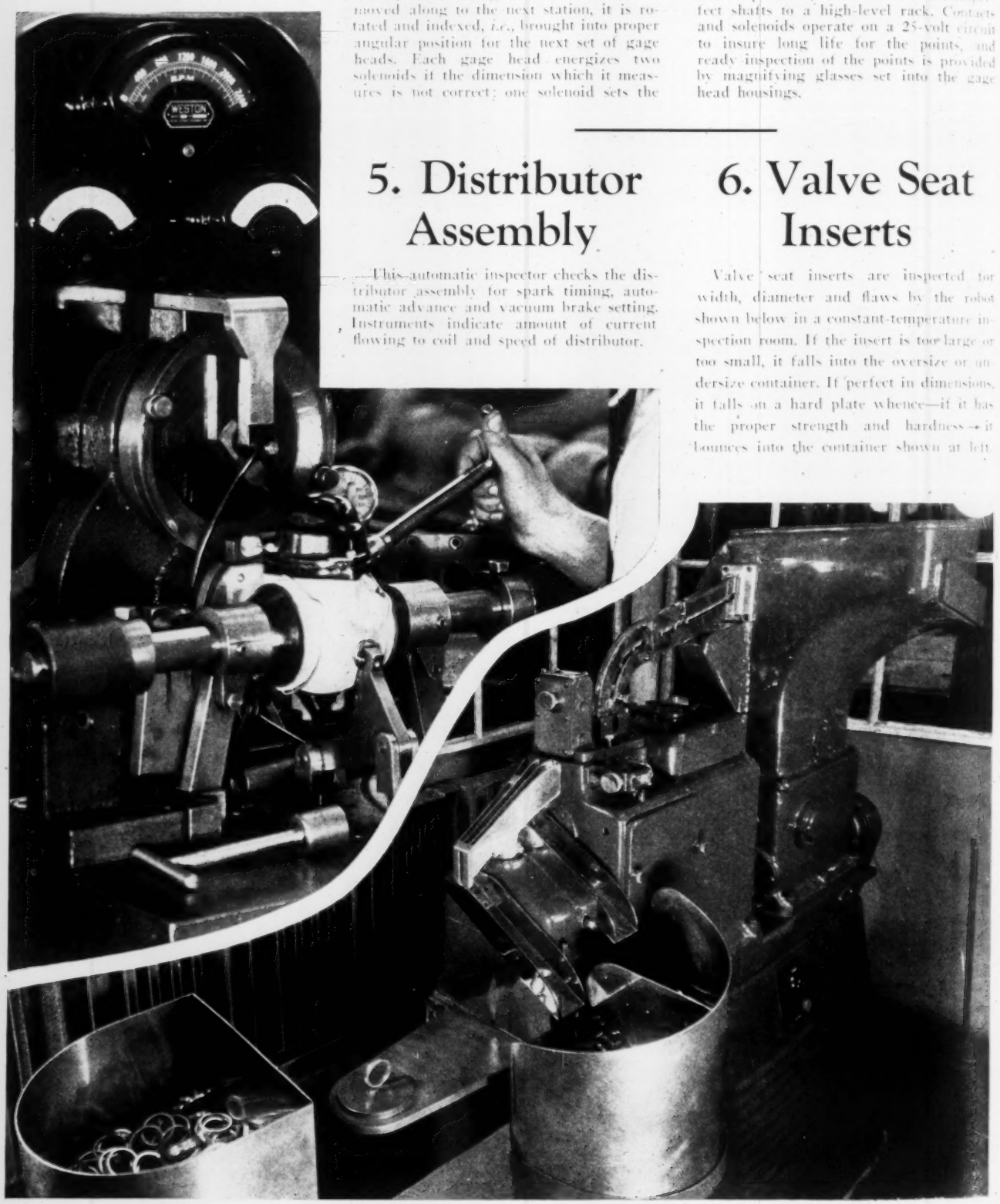
Right—Second station, where hardness is measured by an automatic scleroscope: if hardness is correct, rebounding hammer intercepts light-beam for a certain interval; if pin is not hard enough, hammer does not rebound high enough; if too hard, hammer goes past light-beam.

Bottom—Fifth station, where pins are sorted by diameter and distributed to five trays: (1) oversize; (2) + 0.0001"; (3) ± 0.00005"; (4) — 0.0001"; (5) undersize.

4. Automatic Inspection of Cam Shafts

(see front cover)

Designed and built by the Ford Motor Co., this automatic inspector, the only one of its kind, not only rejects imperfect shafts but also marks the cams or bearings which cause the rejection. Its gaging accuracy is 0.0001". It inspects 500 shafts an hour, each at 25 points, by means of 25 floating gage heads distributed at ten stations, so that there are ten camshafts progressing through the machine at all times, each undergoing two or more inspections simultaneously. Shafts are advanced by an endless linked conveyor. When they reach the stations the conveyor stops momentarily and automatic centers engage their ends, holding them rigidly. Then the 25 gage heads lower automatically, measure the shafts, and rise again. As each shaft is moved along to the next station, it is rotated and indexed, *i.e.*, brought into proper angular position for the next set of gage heads. Each gage head energizes two solenoids if the dimension which it measures is not correct; one solenoid sets the rejection mechanism into motion when that camshaft leaves the machine; the other solenoid daubs the shaft with copper sulphate at the point where it is oversize or undersize. At the outgoing end of the machine are two sets of elevators. One takes the camshafts which have passed inspection to a leather-covered runway where they are passed on for further operations and inspections; the other lifts the imperfect shafts to a high-level rack. Contacts and solenoids operate on a 25-volt circuit to insure long life for the points, and ready inspection of the points is provided by magnifying glasses set into the gage head housings.



5. Distributor Assembly

This automatic inspector checks the distributor assembly for spark timing, automatic advance and vacuum brake setting. Instruments indicate amount of current flowing to coil and speed of distributor.

6. Valve Seat Inserts

Valve seat inserts are inspected for width, diameter and flaws by the robot shown below in a constant-temperature inspection room. If the insert is too large or too small, it falls into the oversize or undersize container. If perfect in dimensions, it falls on a hard plate whence—if it has the proper strength and hardness—it bounces into the container shown at left.

Cathode-ray Oscillograph Auxiliaries

Thirteenth part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in the July 1935 issue.

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

PHOTOGRAPHIC RECORDING OF OSCILLOGRAMS

(*Concluded*)

PHOTOSENSITIVITY OF FILMS

Much progress has been made recently in the development of special emulsions of great utility in photographic work because of their increased color-sensitivity range, but these new emulsions do not possess outstanding advantages for cathode-ray oscillographic recording. Since the spectral distribution of any particular screen fluorescence is rather limited, there is not much need of using emulsions whose sensitivity extends to the reds and infrareds when the colors to be recorded are in the greens and violets. A super-speed film, however, is faster than normal film for the green colors such as obtained with the zinc silicate screen. Panchromatic films and others having similar spectral distribution usually prove no better, in the author's opinion, since they are more likely to become fogged by background lights, whereas the other types require no special darkroom precautions.

Considerable work has been done by many investigators in sensitizing photographic plates in other ways. The most sensitive plates at present are the Schumann plates, or Shumannized plates. The former are made by a process that deposits the light-sensitive salts on the plates without gelatine, and the latter type is produced usually by some process that removes the gelatine from the ordinary plate, leaving only the salts. The sensitivity of these plates is much greater than those with regular emulsion, especially when used inside of the tube itself. Such plates cannot be made by machinery, and must be handled in a special manner. So far as the author knows, they cannot yet be obtained in this country.

SELECTION OF A LENS

A meniscus lens, made of a single piece of glass, is the cheapest type of lens that can be purchased (with the exception of a simple magnifying or reading glass). The next step is the meniscus-achromatic lens, made from two nested lenses of different densities of glass. A simple lens will not have a common focal point for all colors, so that the combination of two lenses of different kinds of glass, so selected that the color discrimination is balanced out, will sharpen the focus when a number of colors are to be transmitted. An achromatic lens will do this. The next step is the rapid rectilinear lens, which is formed of two lens combinations, with a "stop" or light aperture between them. Since such a lens has half the focal length for the same diameter, it is four times as rapid. The location of the stop, between the two lenses, neutralizes out the "pincushion" effect (curvature or distortion toward the edges of the image) and accounts for the "rectilinear" name.

Achromatic lenses, ground with special curvature formulae which tend to produce a flat field image, are called anastigmats. They are the most expensive of the commonly available lenses.

For cathode-ray oscillographic work it is not a difficult problem to select a lens, for several reasons: a single color only is to be transmitted by the lens; this same color is used both to focus the diagram on the ground glass and to record on the film, and in addition the object is a nearly flat surface so that no great depth of focus is necessary. In a permanent set up such as shown the focusing can be carefully done on the ground glass, and there is ordinarily no need for changing the setting as all distances are fixed. An achromatic correction for the lens is therefore of secondary importance. For the same reason part of the superiority of an anastigmatic lens is not so much in evidence for this service, and for lenses of equal speed the advantage seems to be with the R. R. type. This type will correct for the distortion obtained with a wide-open meniscus lens and will at the same time give greater speed. It also is possible to use a cheaper arrangement, such as the lens used in an enlarging camera, or even a plano-convex magnifying glass—although with the latter some correction will be required for non-uniformity of the magnification at the edge of the plate. When such a lens is used the stop should be placed between the lens and screen, as in this position some correction will be introduced for the curvature of the screen.

In the *f*/ system of designating lens stops, the opening diameter (the stop designation) is equal to that fraction of the focal length. That is: a lens opening of 0.5″ with a lens having a focal length of 4″ would be marked *f*/8, which is 4″ divided by 0.5″. Or an opening 0.66″ diameter with a 3″ lens would be designated *f* 4.5.

The distance between the screen and the film will be approximately four times the focal length of the lens, but this distance will vary somewhat depending on the magnification used. In the matter of focusing accuracy an expensive lens, such as an anastigmat, does not require any greater care in focusing than a cheaper lens, *with the same stop opening* but the larger the opening with any lens the greater the accuracy necessary.

MOVING FILM RECORDS

It is evident from the foregoing that the design of moving-film cameras for use with cathode-ray equipment requires the consideration of a number of factors. The width and speed of the film are usually determined by the demand for a high precision in the measurements. Since optical amplification (*i.e.* a reading glass) is always readily obtainable and since precision is not measured by the actual deflection but by the ratio of spot diameter to screen diameter, it is essential that cathode-ray tubes be selected which can be focused accurately. In gas-focused tubes the problem of focusing is up to the operator, but in the more recent electron-focused tubes a great deal depends upon the precision of manufacture and upon the design accuracy. In these tubes it is found in practical cases that the focusing will be satisfactory along at least one axis, even if it does not extend to the ends of the other axis. In recording with moving films, only one set of plates is used and therefore the best pair should be selected by trial: the pair that will deflect the spot to the edges of the screen with least distortion.

It is of course necessary that spherical lenses be used. In the mirror types of oscillographs cylindrical lenses are sometimes used, giving greater illumination, but the conditions inherent with the cathode-ray tube make

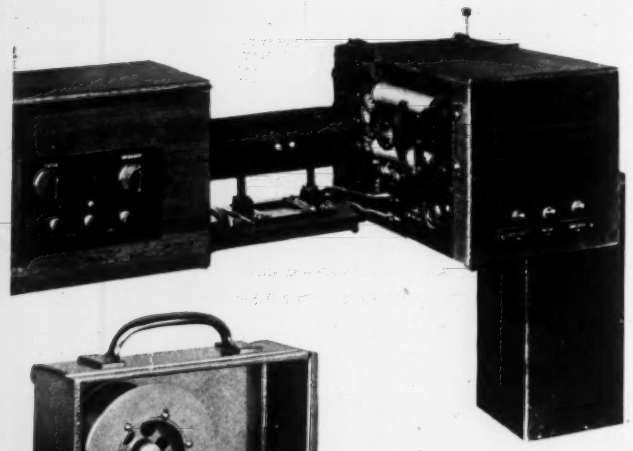


Fig. 3

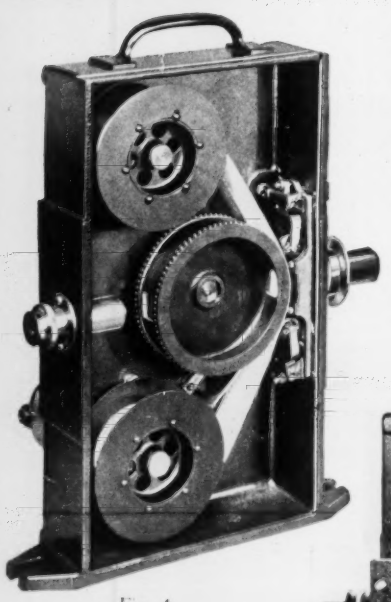


Fig. 4

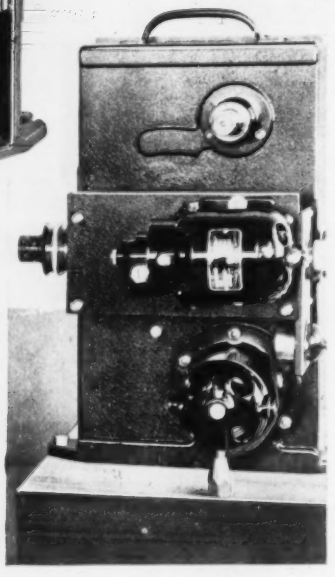


Fig. 5

spherical lenses mandatory: the spot on the screen is a source of light, from which illumination proceeds in practically all directions. In the other system, only a single pencil of light traverses the optical system.

A recording camera built by the author and shown in Fig. 3 utilizes commercial rolls of 3-cm. bromide paper, of the type commonly supplied for electrocardiograph cameras. Due to the relatively slower speed of this emulsion, compared with the faster grades of 35-mm. perforated film, only the lower range of audio frequencies can be successfully recorded. The cathode-ray tube and the controls are located in the wooden cabinet at the left, with its screen facing a lens which is permanently fixed in the metal tube at the center. The image is focused on the paper roll in the third compartment, driven at the required speed past a slit and into a magazine which is mounted to extend over the edge of the table. Speeds ranging from 1″ sec. to 2 ft. sec. are usually employed, for recording psychological effects and other phenomena.

A commercial example of a moving film camera developed by the General Radio Co. has been described recently.[12] As shown in Fig. 4, the unit consists of lens mounting and reels, together with a focusing eyepiece. Focusing is adjusted on the film by means of openings through the sprocket. Various types of motor equipment are available, giving a range of film speeds from about 1 to about 35 ft./sec. Two motors are normally used (as shown in Fig. 5), respectively driving the main sprocket and the take-up reel. The latter motor is a series motor of just sufficient power to keep the film taut, and so to adjust its speed to the diameter of film on the reel. This device eliminates the need of a variable-ratio drive between driving sprocket and take-up reel. The magazine reel has a capacity of 100 feet. Normally 35-mm. perforated film is used, but this camera can be adapted to 16 mm. film.

[12] Anon. Moving film camera. *Instruments*, Vol. 8, 1935, page 54.

EXPOSURE TIME[13, 14]

While there are two distinct problems to be considered: that of recording the transient excursions of the spot, and that of retraced diagrams or closed figures, a single set of rules can be formulated for both. For a given set of operating conditions the important numerical value to start with is the maximum transverse speed of the spot across the screen that will give a distinct trace on a film. For recurrent diagrams the corresponding equivalent velocity is equal to the length of the path of the spot for a complete figure divided by the exposure time.

Some of the factors that must be considered cannot be accurately determined easily, but an approximate solution can be obtained from a semi-empirical relation that has been plotted in the chart Fig. 6. It is necessary to know:

[13] Hartridge. Extending the Frequency Range of the Cathode-ray Tube. *Nature*, Vol. 131, 1933, page 95.

[14] Chapman. Photographing Transients. *Nature*, Vol. 131, 1933, pages 620-621.

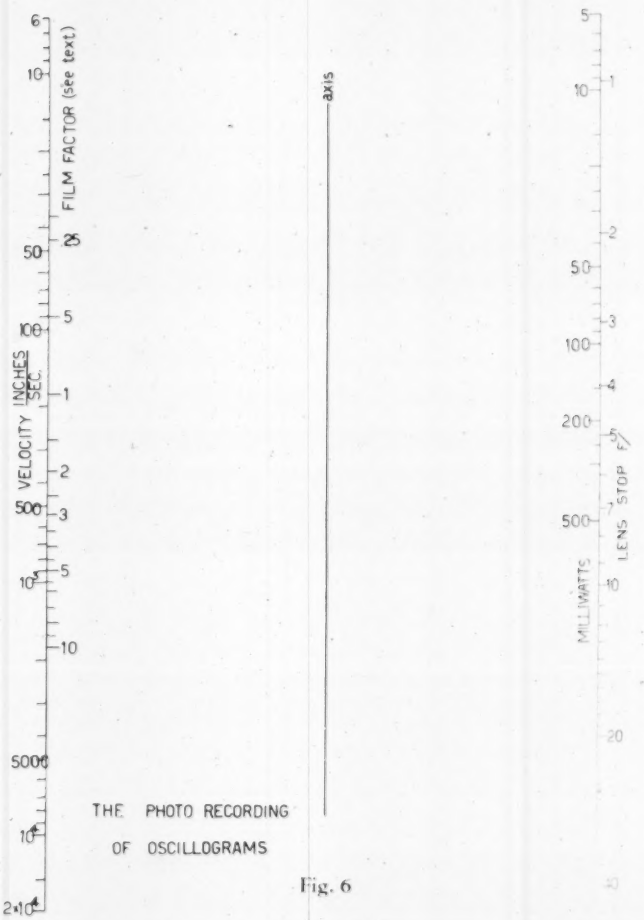


Fig. 6

1. Beam energy in milliwatts: kilovolts on anode × beam microamperes;
2. Film emulsion characteristics;
3. Fluorescent screen characteristics (see Dec. 1935 article);
4. Desired recording size (magnification); and
5. Lens stop.

In using the chart, Fig. 6, it is first necessary to estimate the ratio of the size of the diagram on the film with respect to the size on the screen, and a value is selected on the Film Factor scale according to the type of film used:

Normal film	Use a factor of 0.25
Verichrome, or equivalent	1.00
Super-speed panchromatic	2.00

These values hold for a 1 to 1 record size, and for a willemite screen. For other conditions the value on this scale must be altered as follows:

Recording size ratio =	unity	half	quarter
Correction factor =	1.00	1.9	2.5

For a calcium tungstate screen (such as the RCA 907 or 908) another correction must be made whereby the value is again increased by a factor of 2.5 on an average. For example the "Film Factor" with a Verichrome film, with the record size one-half of that on the screen and using a tungstate screen, would be $1 \times 1.9 \times 2.5 = 4.75$.

A line extended between this value and a point on the "milliwatt" scale equivalent to the product of the anode potential and the beam current will intersect the axis at a certain point. Another line connecting this point of intersection and the value on the "Lens Stop" scale equivalent to the lens opening used will, if extended, intersect the "Velocity" scale at a point indicating the maximum transverse speed of the spot that can be satisfactorily recorded for the conditions assumed. There is no definite rule, however, that is reliable under all conditions. This chart will give average values: it was obtained from averaging a large number of experimental and recorded data. The candlepower of the light output varies with many factors both as to intensity and the spectral distribution. It is usual practice to revise the value of the Film Factor used if in any particular set-up the values assumed give inaccurate results. In fact it usually is easier to make a series of test records and to alter the value assigned to this factor than it is to measure accurately the beam energy in milliwatts.

The candlepower output is not directly proportional to the beam energy. In ordinary circumstances the higher

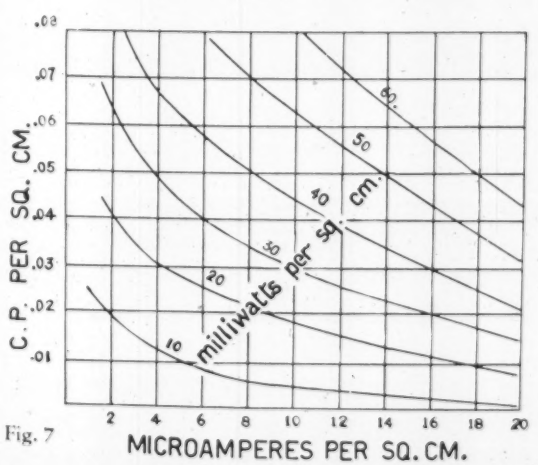


Fig. 7

efficiencies are obtained with high speed electron impacts, that is, with high voltage and low current density. This is shown graphically in the curves, Fig. 7, which show the candlepower output of a normal willemite screen.

A more common problem, that of photographing "solid" figures, can be solved by the same chart, by dividing the indicated spot velocity by the factor 50 and calling the result square inches. A solid figure is one as obtained in certain tests where a diagram is evenly illuminated over its area. If such a diagram is steady on the screen and the operating conditions do not vary, there is no harm of course in increasing the exposure time.

While this chart is primarily designed for indicating the minimum exposure time for a transient, it can be used also for steady recurrent diagrams. Thus, if the chart indicates that a speed of 500″ sec. will produce a record, a steady diagram represented by a folded diagram 20″ long will require an exposure of at least 1.25 sec.

For making daylight records of oscillograph diagrams the author has found useful a special camera such as shown in Fig. 8: A long cabinet (or tube), large enough to contain the 3″ cathode-ray tube at one end, has also an adjustable lens and, at the other end, a film pack adapter and ground-glass plate arranged so that either may be set at the focal plane. The total length of the cabinet depends on the length of the cathode-ray tube and the focal length of the lens, and to some extent upon whether the photograph is to be larger or smaller than the screen. It has been found convenient to use the tube cutoff bias as a "shutter" to control exposure time.

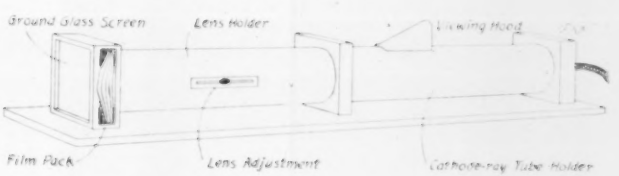


Fig. 8

It is possible to view the screen from the back during the recording interval, for which purpose a viewing hood is provided.

In the design shown, a $2\frac{1}{4}$″×$3\frac{1}{4}$″ film pack is used, for a 3″ screen diameter. The lens opening is *f* 1.9, giving ample speed. A power supply is permanently affixed to this unit so that the application of the deflection voltages only is necessary in actual use.

CIRCULAR PHOTOGRAPHS

In the investigation of waveform with circular diagrams it may simplify the interpretation if a circular photograph is made of the figure. The spot may be rotating in a circular path and will show up as a circle or ellipse with the usual photograph. If, however, the film is rotated at a synchronous speed in its own plane, the spot will either rotate at a double frequency or else will appear stationary, depending on the relative direction of the motion.

The latter condition is of interest. If the original diagram is a true circle, the record is a single spot. An ellipse will be recorded as a smaller circle whose diameter is equal to the eccentricity of the ellipse. The figures resulting from the presence of higher harmonics will be discussed in another article.

A camera suitable for such a test can be made up similar to that in Fig. 8, but the film is clipped to a motor-driven disk located in the focal plane.

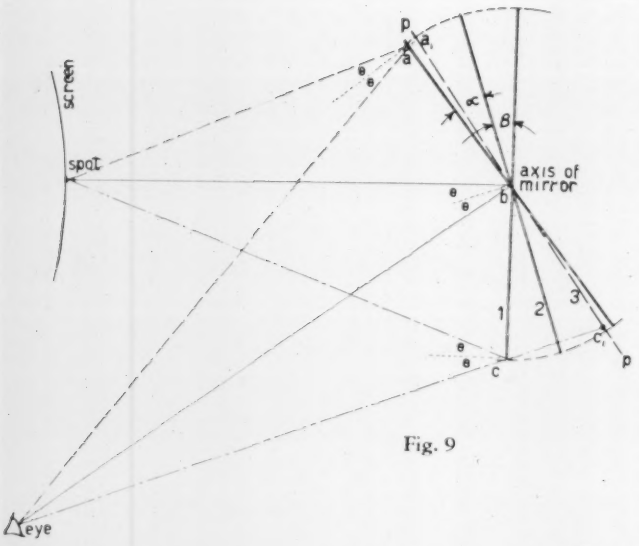


Fig. 9

ROTATING MIRRORS.

A rotating mirror is ordinarily of little importance in conjunction with a cathode-ray oscillograph, especially when used to produce a mechanical time base for visual work. In this application the problem is entirely different from that usually encountered when mirrors are used with other types of oscillographs: the source of light with a cathode-ray tube is a primary source and a cone of rays reaches all points of the mirror. In other oscillographs a single pencil of rays is projected so as to be intercepted by the mirror at a single point, and the reflected ray is also in the form of a single beam.

Since the eye is stationary, the process can be described with reference to Fig. 9. Here a plane mirror is rotated about a vertical axis (at point b) and successively occupies 1, 2, 3, . . . , once (or twice if both surfaces of the mirror reflect) during each revolution. Assume that the mirror is in position 1. All points of the reflection area will intercept rays from the fluorescent spot but there is but one point on the mirror where the reflected ray will reach the eye (as at the point C). At this point the angle of reflection and the angle of incidence add up to the angle, measured at the surface of the mirror, between the spot on the screen and the eye.

As the mirror moves the apparent location of the spot will move and at angular position (2) of the mirror it will appear at the center at point b. At mirror position (3) the spot will reach the eye after being reflected from the point a at the opposite edge of the mirror. As the mirror advances farther the spot will no longer reach the eye, until a reflection surface again reaches position 1. Actually the spot appears to the eye to be moving across a non-physical plane $p-p$, which may be assumed to be normal to the plane which includes the axis of the mirror and the eye. That is, the spot apparently moves from C_1 to b to a_1.

As the spot on the screen is deflected in a direction perpendicular to the page, this same motion is projected in such a way that the eye will see the wave-form spread out with a time base, which may or may not be linear, depending upon relative distances between the screen, the mirror and the eye. This method is rather inefficient with the light since for a relatively large portion of the time the ray is not projected toward the eye. Some improvement is obtained if a multi-sided mirror is used, with all faces equidistant from the center of rotation.

A similar analysis will show that this method is unsuited to photographic recording as well, without the inclusion of a properly focused lens either in the path between the screen and the mirror or between the mirror and the recording film. Since a short focal length lens is necessary in order to increase the light transfer, some difficulty will be experienced in getting accurate focusing on the mirror surface.

The mirror is preferably of polished metal without a glass facing, to eliminate multiple reflections from the double glass surfaces. Since the spot is visible for only a small portion of a revolution the mirror need not be rotated faster than one revolution for about twenty cycles of the wave-form under investigation, but the speed should be synchronized with that wave so that successive traces are superposed.

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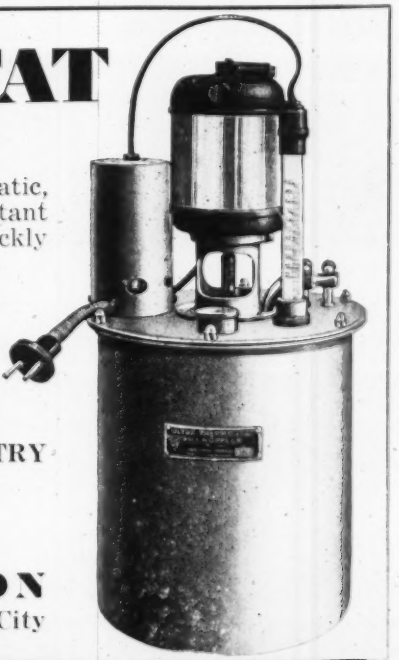

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By PERRY A. BORDEN and M. F. BEHAR
Member A.I.E.E. Editor, *Instruments*

1. Introductory.

In the opening paragraphs of this series it was hinted that since the *general* subject of "Electrical Control" was one of electrical engineering rather than of electrical instrumentation, our treatment of automatic control would be confined solely to the automatic regulation of the measurable and purely electrical magnitudes such as voltage; and would not include any of the manifold applications of electrical methods of controlling non-electrical magnitudes and phenomena. Even the automatic control of measurable voltages and currents (to say nothing of frequency, synchronism, etc.), is in itself a subject so broad and so ramified as to justify a much lengthier treatment than can be logically allotted to it here; so that it will be necessary to restrict the discussion to a few descriptive statements regarding the outstanding practical methods whereby electric voltages or currents may be caused to attain and maintain predetermined values.

Though the essential principles of automatic control as set forth in Part One[1] may be looked upon as universal, the problems attending the regulation of electrical magnitudes are in general quite different from those involved in controlling temperature, flow, liquid-level, speed, illumination, hydrogen-ion concentration, and other physical and chemical variables encountered in industrial practice. The prime objective in the automatic control of electrical magnitudes is in most cases that of maintaining a constant value of electromotive force at the terminals of a source of electrical energy or at some predetermined point in a circuit supplied from that source.

Self-regulating properties may be incorporated in the design of direct-current generators to the extent that a desired voltage characteristic as related to load conditions may be incorporated in the machines, and by suitable design of their electromagnetic systems, made adjustable to meet a wide variety of conditions without the need for accessory equipment. These features, involving the proper proportioning of shunt and series fields into compound windings, are essentially elements of electrical machine design, rather than of instrumentation, and will be found fully discussed in elementary textbooks on electrical engineering.

The incorporation of self-regulating features into generating machinery does not always give the desired degree of flexibility, nor does it provide for changes in the speed of the prime mover. Again, on large machines, the cost entailed by the addition of series field windings may become a dominating figure and justify a considerable expenditure on automatic control equipment to permit limitation of the exciting circuits to a simple shunt winding. Alternating-current machines are not inherently self-regulating, and the first application that suggests itself lies in the provision of accessory equipment to accomplish this result in response to (or in spite of) extraneous variables. This problem has been recognized since the earliest days of electric power applications, and innumerable solutions have been offered. Many of these have been eminently satisfactory, and up to the advent of the thermionic tube such systems had become well standardized and were available in forms to suit almost any type and size of installation. Recognition of the properties of the vacuum tube and of the dry-type rectifier has led to simplification in self-regulating devices, so that the art may be said to be again in a transitory state; and almost every issue of the electrical engineering periodicals discloses new instrumental methods of effecting regulation.

Another aspect of the problem, wherein there exist many opportunities for compromise between machine design and the development of regulating appa-

[1] Fundamentals of Instrumentation, Chapter III.

ERRATUM. In the last instalment a line of type was dropped out of the last sentence. It should read: ". . . one may be assured that **something is seriously wrong and that the instrument should not be used until** it has been repaired."

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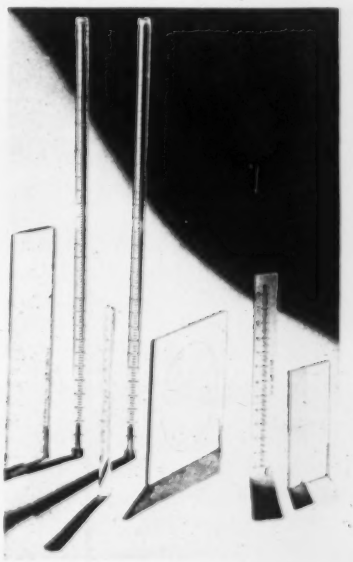

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ratus, is that of feeder voltage regulation; and here again is to be found a host of new developments.

Many of the new developments in electrical regulators are thus based on discoveries or advances in other branches of science and technology; most of them, however, owe their appearance to the spread of Instrumentation's basic idea of associating control with measurement, to Instrumentation's doctrine that before a condition can be controlled it must be measured, to Instrumentation's challenge that whenever a variable has been made measurable it can be made controllable.

2. Classifications.

Because the art is in transition at this time, any comprehensive classification is doomed to a brief useful life—especially in view of the fact that the definition of classes and types, and of various component elements, must themselves undergo revision with each advance. There is no definition of "regulator" which could serve satisfactorily as the basis of a permanent scheme of classification; and the difficulty of defining various component elements is illustrated by the term "vacuum tube" which, through the force of usage, covers the newer gas-filled tubes whose characteristics (admirably suited to many automatic-control uses) cannot be obtained under high-vacuum conditions.

The variety of methods whereby different mechanical, electromagnetic and electronic elements may be embodied in a single regulator would make a complete classification into mutually-exclusive categories too complicated as well as too impermanent. So would the variety of mechanical, electromagnetic and electronic phenomena or principles which may be utilized in a single regulator.

To be sure, there are other conceivable schemes whereby all regulators can be classified into mutually-exclusive categories. For example the scheme

Class I—Regulators without moving parts
Class II—Regulators with moving parts

could be used as a starting-point, but it obviously is not based on sufficiently important considerations for classifying complete regulators. However, this scheme is useful in classifying the measuring elements of regulators, and the authors thus make use of it below.

A classification on the basis of the electrical magnitudes to be automatically regulated suggests itself: There are not only automatic voltage and current regulators but automatic demand-limiting devices, automatic synchronizers, automatic frequency regulators for industrial plants and automatic frequency monitors for broadcasting stations, and so on. This is the most logical scheme, but essential similarities preclude here a comprehensive treatment based entirely on it. Our main discussion will deal with voltage regulators, and will include brief descriptions of other regulators, without touching upon non-industrial devices. Practically all principles to be discussed as utilized in voltage regulation are applicable to current regulation but are seldom utilized for that purpose.

There follow three groupings, more or less arbitrary, not to be looked upon as dividing regulators into scientific categories, but providing a sort of convenient "table of contents" of the subject. Automatic regulators may be classified according to any one of these three schemes—

(A) The *combination* of the electrical magnitude to be regulated (in this treatment, *voltage* or *current*) and the *point* in the system at which regulation is to be effected. Thus:

Generator voltage regulators
Feeder voltage regulators
Feeder current regulators

Notes. (1) It is obvious that regulation will be effected either in the generator or at some point between the generator and the point of utilization of the power. (2) Generator current regulators (automatic) are conceivable but non-existent since constant voltage is the universal requirement; even "feeder" (or "application") current regulators are seldom met with outside of constant-current lighting systems, furnaces, plating baths, etc.

(B) The *measuring element*. Primary or sensitive elements which command the operation of voltage or current controlling devices in regulators may be grouped as follows:

Class I. KINETIC
- Type 1. Electromagnetic elements;
- Type 2. Other elements in which variations in the controlled magnitude are represented by *mechanical displacements*;

Class II. Static	Type 3.	Saturable magnetic circuits;
	Type 4.	Electronic devices;
	Type 5.	Circuits utilizing non-linear resistances.

Notes. (1) Kinetic (or dynamic) elements are those with moving parts; and the term static refers of course to absence of mechanical displacements, not to the use of electrostatic forces. (2) All practical embodiments of kinetic measuring elements in automatic regulators correspond to electromagnetic types of ammeters and voltmeters, so that Type 2, which covers thermal elements, electrostatic elements, etc., is seldom met with in practice.

(C) The *controlling element*. Actual final regulation of current or voltage may be effected by control devices commanded by the measuring elements and operating on one or more of the following principles:

Excitation control	1	Vibrating;
	2	Rheostatic;
	3	Electronic;
Feeder control	4	"Boosting" and "Bucking";
	5	Reactive;
	6	Bridge networks.

The above triple-scheme classification is admittedly incomplete; and for reasons already given the various types of regulators cannot conveniently be discussed in the order of any of the groupings; yet, in the treatment which follows, a definite attempt is made to discuss the different kinds of regulating devices and systems in a logical sequence and, as far as possible, in natural association.

3. Control of Generator Voltage.

In some early forms of dynamos (and in some modern units of small sizes and specialized designs) control of terminal voltage is effected through variation in the number of active armature conductors, by automatically changing the position of the brushes on the commutator. In general, this practice is inefficient and likely to introduce more problems than it solves. The almost universal method of controlling generator voltages at present is to alter the value of the magnetic flux in which the armature windings operate, by altering the current flowing in the exciting windings. The oldest, and probably the most common, way of doing this is by adjusting the resistance of the field circuit; and it is toward the regulation of this resistance that most of the systems of automatic generator voltage control are directed.

It will be observed that the sensitive elements of the majority of regulators acting upon field excitation are of the type in which the mechanical reaction of an electromagnetic device is utilized.

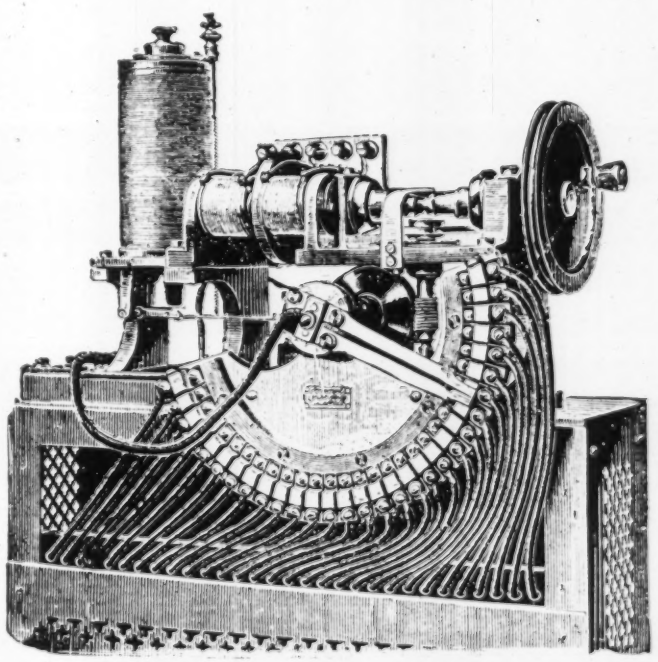
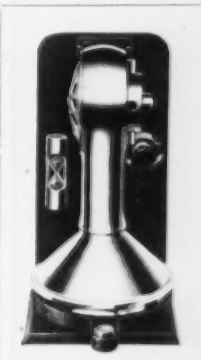


Fig. 48-1



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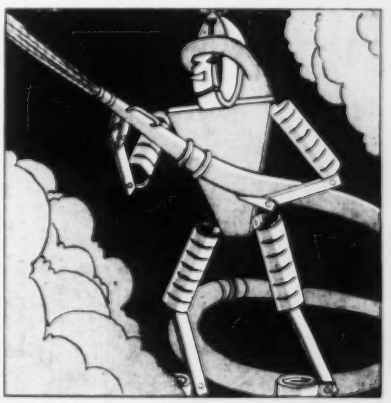

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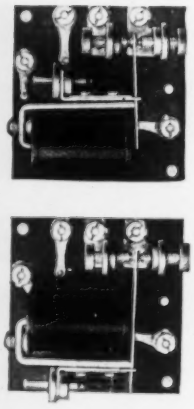

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(a) The Simple Rheostatic Regulator.

Early developments in power plant equipment included a number of forms of automatically adjusted field rheostats in which a traveling contact arm is moved by a power unit governed by the voltage under control. It is obvious that where the main field rheostat of a generator is thus controlled, the apparatus necessary for large units would be cumbersome and slow in action. Consequently, in modern practice such systems are seldom used except on the exciters of small alternators. An early form[2] of rheostatic regulator of this type developed by Thury is shown in Fig. 48-1. The small wheel at the right is driven slowly from the shaft of the engine. (This regulator antedates a ready supply of small motors.) The magnet coil seen on the left is excited from the voltage to be regulated, and throws into gear one of two bevel wheels which act to drive the rheostat according to whether conditions demand an increase or a decrease of voltage. While this seems a crude form of automatic regulator today, its mechanical principle is retained in a modified form, and in combination with more refined control elements, in a number of modern regulating devices.

(b) The Oscillating Regulator.

An interesting controller of wide application, also due to Thury, is that shown in Fig. 48-2. A fixed coil *F* and a movable coil *B* on a common magnetic circuit form a measuring element, causing a lever *E*, carrying a small toothed detent *C* to move above or below a balance position, as determined by a calibrating spring *A*. A rocking lever *D* carries two latches or pawls *I* and *I'*, normally held in their topmost position by tappets *K* and *K'*, the whole being caused to rock continuously at about 100 strokes per minute. When the voltage or other magnitude to be regulated is at its normal value the lever *E* is

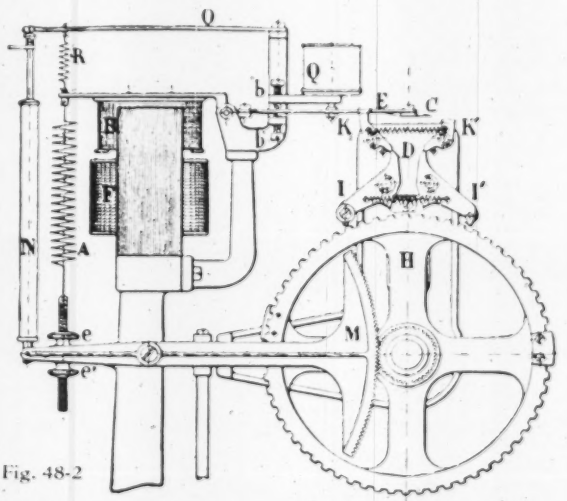

Fig. 48-2

held in a position where the tappets clear the detent. When a deflection takes place, one of the tappets is engaged and the corresponding pawl thrown into engagement with the toothed wheel *H*, so that the wheel will be advanced during the oscillation of the lever, and by a direct mechanical connection shift the arm of the field rheostat through a corresponding angle. A gear sector *M*, acting upon the balance lever *E* through a dashpot *N* and a spring *R*, tends to restore the balance and prevent over-control. Fig. 48-3 shows a diagram of this form of regulator directly connected to the main field rheostat of an alternator.

In European practice the oscillating mechanism has been widely applied to the automatic regulation of feeder voltages by multiple-tap transformers and induction regulators, but for power plant practice has to a great extent been replaced by simpler and faster devices. (This form of regulator, however, still has considerable use in the control of carbon electrodes in arc furnaces of the Héroult type.) The most modern European practice makes use of hydraulically operated field rheostats commanded through relay mechanism by voltage sensitive units of the electromagnetic type, in a manner similar to fluid operated speed governors. The best known of these is probably the "Rex" regulator, supplied by Cuénod of Switzerland, shown diagrammatically in Fig. 48-4.

[2] U. S. Patent No. 435,332. R. Thury, Aug. 26, 1890.

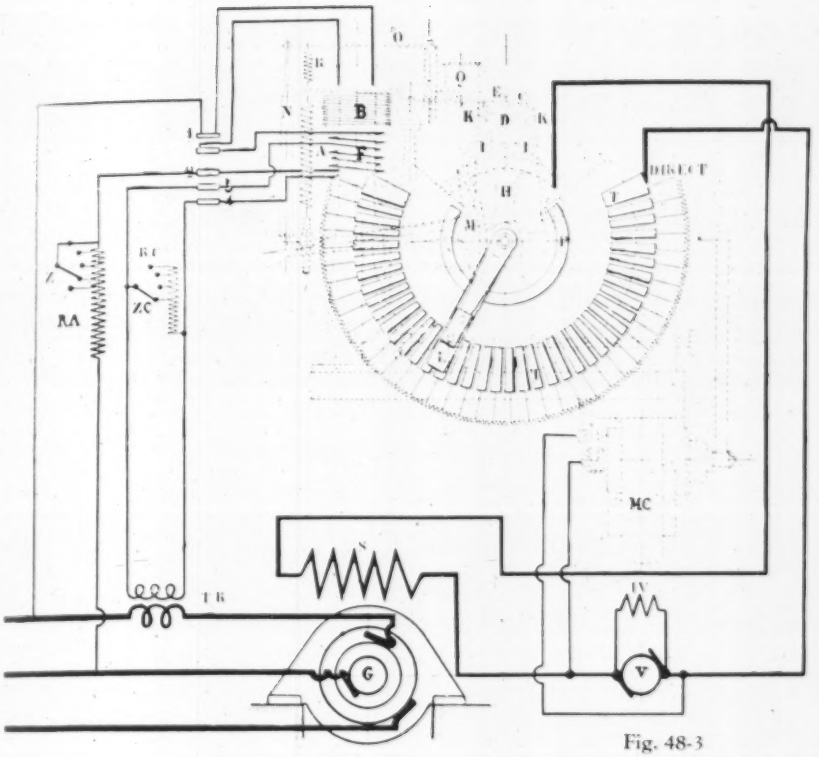

Fig. 48-3

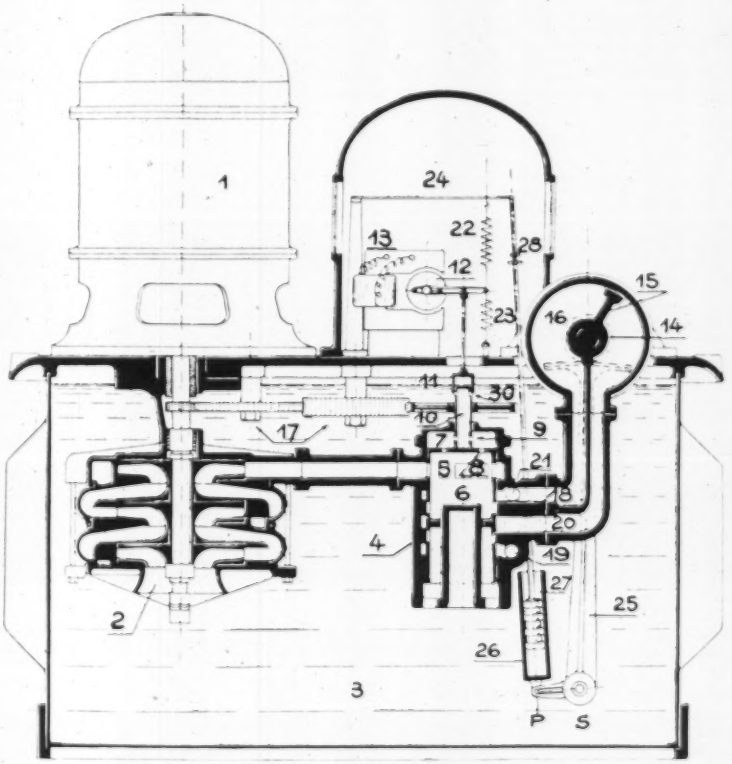

Fig. 48-4

(c) Recent American Rheostatic Regulators.

A representative line of modern rheostatic regulators, available in both a-c. and d-c. forms, is the General Electric "FA" line, the regulating mechanism or "control head" of which is shown in Fig. 48-5. Excitation is controlled by automatic adjustment of the field rheostat, coupled with the action of high-speed relays which under extreme conditions cut in or out the entire regulating resistance in the field. The voltage-sensitive element is a torque motor responsive to circuit changes, and having its pull balanced against that of a

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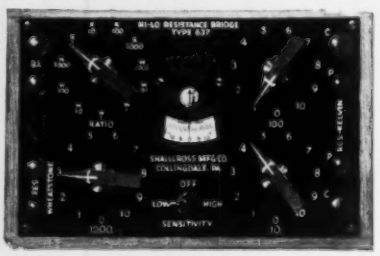

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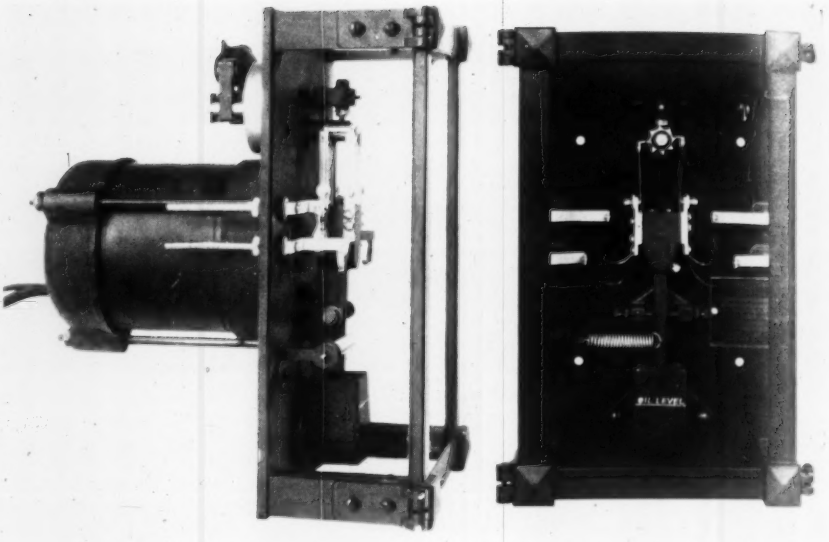

(Side) Fig. 48-5 (Front)

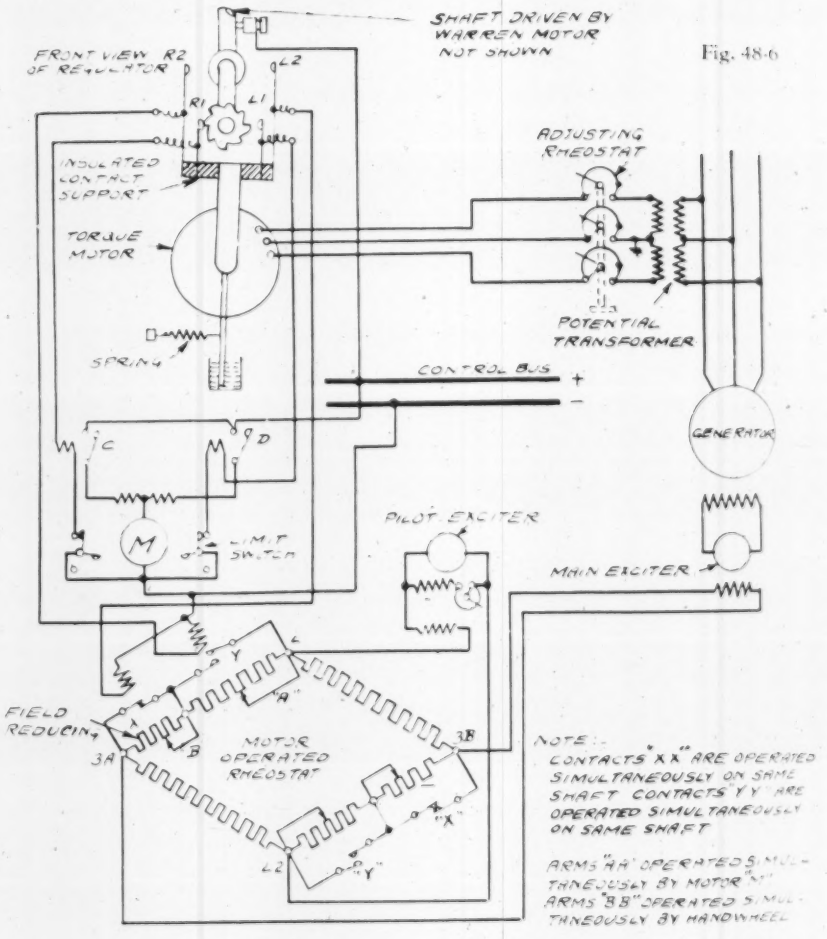

Fig. 48-6

helical spring. (See also Fig. 48-6) Two pairs of contacts, carried by the shaft of this motor, are positioned to embrace a contact wheel continuously driven by a Telechron motor. A magnetic damper prevents oscillations of the torque motor. The contact wheel has two elements, one notched, and the other continuous. As long as the generator voltage remains constant (within 0.5% of normal) the torque motor is balanced, and both pairs of contacts are out of engagement. Upon slight changes in voltage, one of the main contacts engages the notched wheel, and a notching relay progressively advances the field rheostat in the proper direction. When large variations of voltage occur (20% or more) the continuous periphery of the wheel is engaged by one of the high speed contacts, whereupon relays act to cut all the regulating resistance into or out of circuit, giving a maximum rate of response.

(c) The Rocking-contact Regulator.

The rocking-contact type of regulator, originated in Switzerland by Brown Boveri, and produced in America by the Allis-Chalmers Co., represents another modern refinement in the regulation of generator voltage by direct adjustment of the field rheostat. Fig. 48-7 is a diagram of this device in its elementary form. The exciter field rheostat, indicated at g, actually forms, with the contact structure, an integral part of the regulator, as shown in Fig. 48-8. The stationary contacts, to which the resistance coils are connected, are arranged about a circle in two or four rows, depending upon the size of the

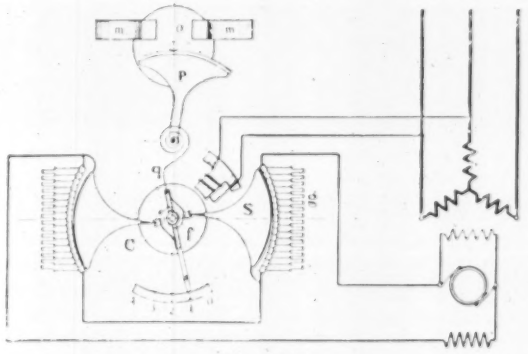

Fig. 48-7

regulator. The inner face of these contacts is provided with a V-shaped groove that serves as a guide for the moving contact-sector S. The latter has a contact face curved to a radius smaller than that of the contact circle, and terminates toward the center of the circle in a steel point resting in a jewel cup mounted on a leaf spring, so that the contact sector is firmly pressed into rocking engagement with the contact circle. The leaf springs are carried on a rotor spindle, so that the cups in which the steel points are pressed may rotate about the spindle a short distance from its axis, through an angle of about 60 degrees. Thus, as the spindle is rotated, the contact sectors rock on the stationary contact circle and connect into circuit, according to their position, more or fewer of the field rheostat coils. Torque is applied to the spindle by a split-phase motor (or, in smaller sizes, by a solenoid) energized from the line and opposed by a suitable spring, so that the position of the sectors is directly subject to the voltage. Overshooting and excessive fluctuations are prevented by

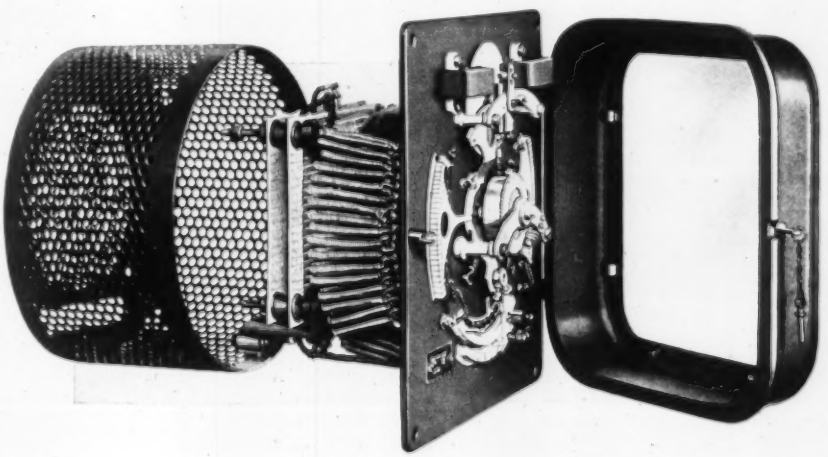

Fig. 48-8

a magnetic damper in the form of an aluminum disk O rotating in the fields of permanent magnets M and driven from a gear quadrant S, which is in turn connected to the main shaft by a flexible spiral spring, q. The device is so proportioned and adjusted that the initial movement of the sectors effects an over-regulation on the exciter field current sufficient to overcome the inherent inertia of the electromagnetic system, after which the action of the magnetic damper allows the sectors to come to rest in a position corresponding to correct excitation. Where several small machines are operating together it is possible to segregate the contact sectors and associate individual rows of contacts with the fields of respective units.

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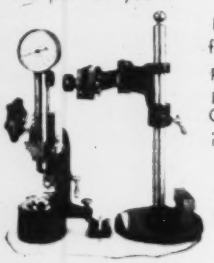

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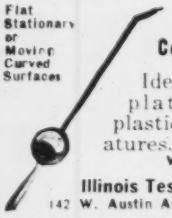

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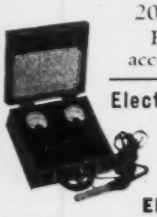

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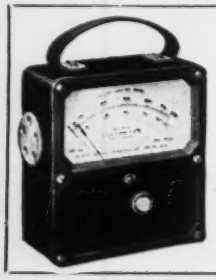

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(e) "Carbon-pile" Regulators.

For the control of small generators operating through a wide range of speeds or under conditions of extreme vibration, the so-called carbon pile, in conjunction with suitable voltage-responsive compressive means, provides a simple and effective voltage regulator.[3-5] The contact resistance of a stack of carbon or graphite plates undergoes a marked variation with the mechanical pressure to which the stack is subjected. An assembly of such plates is connected in series with the field of a generator and placed under proportional pressure from a lever operated by a solenoid or by a torque motor energized from the voltage to be regulated. Any change in voltage affects the

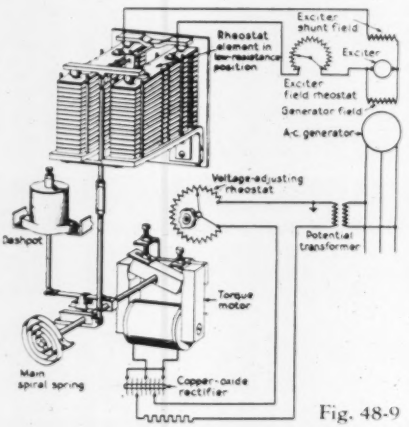

Fig. 48-9

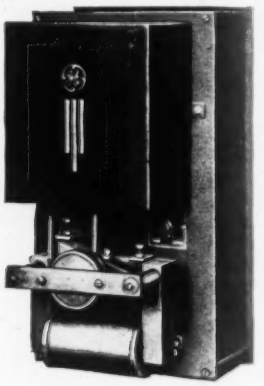

Fig. 48-10

pressure on the carbon pile, varying the resistance in the field circuit and thus quickly and smoothly adjusting the voltage to the proper value. Such regulators are used for voltage control of lighting circuits, railroad car battery charging, a-c. and d-c. generators, synchronous motors, etc. Figs. 48-9 and -10 show a torque-motor primary-element type of carbon pile regulator supplied by the General Electric Co. Its rheostat is of a new form (announced in 1935) employing shaped silver contact strips to reduce the operating pressure. A somewhat simpler G.E. compression-rheostat voltage regulator has a voltage responsive and rheostat-compressing element in the form of a solenoid.[6]

An interesting carbon pile regulator is built by the Safety Car Heating and Lighting Co., but, on account of its circuit, it will be described in Section 5.

(f) The Vibrating Regulator.

The vibrating regulator depends for its operation upon the repeated make and break of a short-circuit across a resistance in series with the field of the generator to be regulated, or, in the case of an alternator, of the exciter field. The relative durations of the intervals of closed and open circuit are governed by the value of the regulated voltage and in turn determine the average value of excitation in the field windings. An elementary diagram of the vibrating regulator as developed by Tirrill is shown in Fig. 48-12* in which the essential parts are designated. The action of the regulator is as follows: Supposing the main contacts to be open, only one winding of the differential relay is energized, and the relay acts to open its contacts, introducing resistance into the field circuit and lowering the terminal voltage of the generator. This weakens the control magnet, which may be looked upon as a contact-making voltmeter; and, under the influence of a calibrated spring, the main contacts are closed, energizing the corresponding winding on the differential relay and reducing its magnetism to the extent that the contacts are again closed, short circuiting the field rheostat and allowing the terminal voltage to rise. This cycle is repeated indefinitely, so that both contacts are continually vibrating, the relative intervals of closed and open contact being automatically adjusted so as to maintain a substantially constant voltage at the terminals of the generator. In large units the field rheostat is subdivided, so that a number of contacts in series are simultaneously inserted in the circuit, together with condensers which minimize sparking. The requirements of modern practice have resulted in many refinements of design and construction.

[3]E. H. Wolff. Carbon Pile Regulators. *Electric Journal*, Feb. 1930, Page 101.
[4]J. H. Ashbaugh. Automatic Regulators in Industries. *Electrical Engineering*, Vol. 5, May 1931, Page 363.
[5]Dodge and Thompson. Development and Use of Generator Voltage Regulators. *General Electric Review*, Feb. 1935, Pages 77-83.
[6]Generator Voltage Regulators. *Instruments*, March 1935, Page 84; June 1935, Page 167.
*Figs. 48-12 and 48-13 are from Karapetoff's Experimental Electrical Engineering, John Wiley & Sons, 1922.

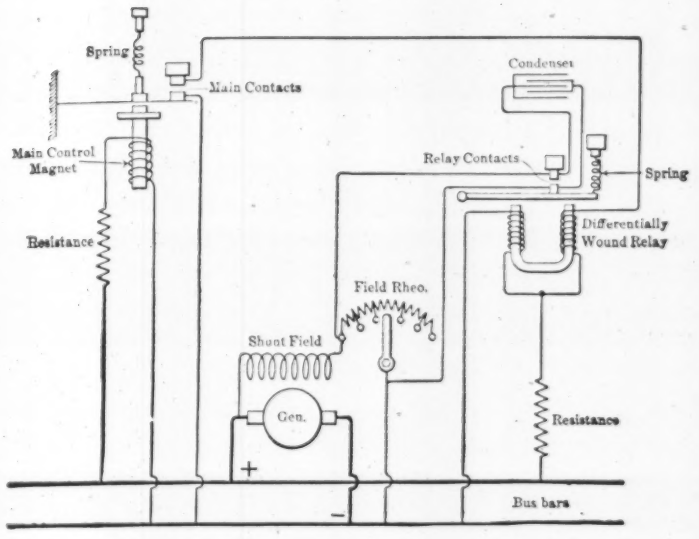

Fig. 48-12

The vibrating regulator has found almost universal application in modern a-c. practice; and an elementary diagram of an a-c. installation is shown in Fig. 48-13. The main contacts of the regulator, instead of working on the generator field, act to short-circuit the field of the exciter, thus not only permitting a much lighter design, but the elimination of possible voltage ripples due to the pulsating action of the contacts. It will be observed that both the main contacts are movable, one being subject to the a-c. voltage to be regulated and the other to the terminal voltage of the exciter. The vibrating action of the main contacts is established by fluctuations in the exciter voltage, these being damped out in the a-c. voltage by the field inductance of the main generator, so that the contact controlled by the a-c. voltage tends to position itself rather slowly, and thus to control the durations of impulses established by the vibrating contacts.

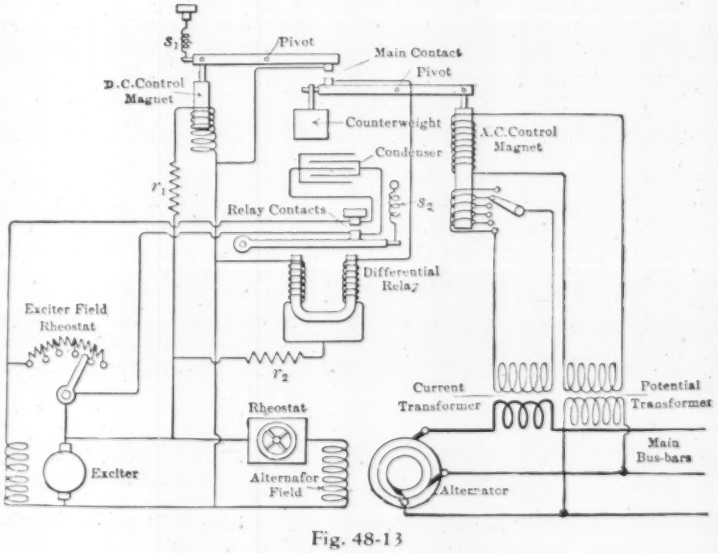

Fig. 48-13

Compensation for load is shown in the diagram, the a-c. magnet having an auxiliary winding fitted with taps and energized by the line current. By selecting the proper tap on this winding, there can be added to the effect of the voltage coil a reaction which may be made to provide compensation for line drop and maintain a desired voltage at any point on the system supplied. By giving the two windings a common magnetic circuit it is possible also to include in the regulation a compensation for load power factor. This is accomplished by connecting the voltage and current windings to the system in such a manner that at unity power factor the currents in the two coils are in quadrature, and at zero power factor in phase-opposition with each other. Thus the controlling action tends to increase with lowering power factor, under which conditions greater excitation is required.

MANUFACTURERS' NEW LITERATURE

In this department we list each month the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm.

D182 **Micromax Thermocouple Pyrometers.** 52-page Catalog N-33A, written in simple, non-technical language and well illustrated, explains the potentiometer method of measurement and the operation of mechanisms through which this balance method is made available to industry. The new Silver-Anniversary Micromax is described in detail. Set forth for ready comparison is the complete Micromax line: appropriate models to indicate, to record, to signal, to control or to perform these functions in any desired combination. Included also are data on couples, accessories, supplies, etc. Leeds & Northrup Company, 4955 Stenton Avenue, Philadelphia, Pa.

D183 **Hydrogen-Ion Meter.** 4-page folder describes the new Beckman pH glass electrode meter. Specifications and prices are included. National Technical Laboratories, 3330 East Colorado St., Pasadena, Calif.

D184 **Round Chart Electric Recorders.** 4-page bulletin No. R covers round chart electric recorders for remotely recording humidity and temperature. Julien P. Friez & Sons, Inc., Baltimore St. & Central Ave., Baltimore, Md.

D185 **Polariscope.** A polariscope for testing strain in glass which will accommodate glass vessels up to 1 gallon bottle size is described in a 1-page folder of R. Fuess, Inc., 245 W. 55th St., New York City, N. Y.

D186 **Lenses, Prisms, Mirrors.** 20-page Catalog D-10 lists various type lenses, prisms and mirrors as well as quartz optical parts. Bausch & Lomb Optical Co., 615 St. Paul St., Rochester, N. Y.

D187 **General Radio Experimenter.** The May 1936 issue of this house organ describes a precision tuning fork and gives winding data for Type 677-U and Type 677-Y coil forms. It also includes annual index for Volume 10; June 1935—May 1936. General Radio Co., 30 State St., Cambridge A, Mass.

D188 **Surge Protector Arc Suppression Products.** A 4-page Folder 1436 describes these units and gives oscillograms. Sundt Engineering Co., 4238 Lincoln Ave., Chicago.

D189 **Controller for Temperature, Liquid Level and Pressure.** Bulletin No. 444 on the new Model 90 Pneumatic type controller for temperature liquid level and pressure, describes its principle of operation and gives data concerning its application. The Bristol Co., Waterbury, Conn.

D190 **Silver Anniversary Micromax.** Leaflet F-N33A is an advance announcement of a new catalogue N-33A which contains complete description of the new Silver Anniversary Micromax. Leeds & Northrup, 4955 Stenton Ave., Philadelphia, Pa.

D191 **History of the Measurement of Length.** Form No. 7318 contains interesting story of the linear standard cubit, digit, palm, inch and foot, yard, and rod. Johansson Division, Ford Motor Co., Dearborn, Mich.

D192 **Orifice Meters.** Publication 2092 describes and illustrates the principle of operation of the new Cochrane orifice meters. Cochrane Corp., Allegheny Ave. & 17th St., Philadelphia, Pa.

D193 **Testing Machines.** Among recently issued Baldwin-Southwark publications is 8-page Bulletin No. 99 on the Southwark-Heydekampf Testing Machine, tracing its development, explaining its principles, and discussing the Iso-Elastic spring. Baldwin-Southwark Corp., Philadelphia, Pa.

D194 **Temperature Controls.** 4-page Bulletin on Model D for temperatures from 50 to 1400°F., and leaflet on Model H which has a 21¾" tube. Burling Instrument Co., 241 Springfield Ave., Newark, N. J.

D195 **Refractometers.** 12-page Catalogue D-202 covers theory, design and application of the refractometer; describes the Abbe and dipping types; includes price list. Bausch & Lomb Optical Co., 615 St. Paul St., Rochester, N. Y.